Government of Canada
Gouvernement du Canada
Canadian Forestry Service
Service canadien des forêts

Proceedings of the 1984 Prairie Federal-Provincial Nurserymen's Meeting

E M Harvey, compiler

Information Report NOR-X-274
Northern Forestry Centre

86-05809/

The Northern Forestry Centre (NoFC) of the Canadian Forestry Service is responsible for fulfilling the federal role in forestry research, regional development, and technology transfer in Alberta, Saskatchewan, Manitoba, and the Northwest Territories. The main objectives of the center are research and regional development in support of improved forest management for the economic, social, and environmental benefit of all Canadians. Since 1982 the center has also assumed responsibility for the implementation of federal-provincial forestry agreements and employment stimulation programs in the forestry sector.

One of six regional centers, two national forestry institutes, and a headquarters unit, NoFC is located in Edmonton, Alberta, and has district offices in Prince Albert, Saskatchewan, and Winnipeg, Manitoba. Until joining Agriculture Canada in 1984 under a Minister of State (Forestry), the Canadian Forestry Service was part of Environment Canada.

PROCEEDINGS OF THE 1984 PRAIRIE FEDERAL-PROVINCIAL NURSERYMEN'S MEETING

September 11–12, 1984, in Edmonton, Alberta

E.M. Harvey, compiler

INFORMATION REPORT NOR-X-274

NORTHERN FORESTRY CENTRE
CANADIAN FORESTRY SERVICE
1986

©Minister of Supply and Services Canada 1986
Catalogue No. Fo46-12/274E
ISBN 0-662-14324-8
ISSN 0704-7673

This publication is available at no charge from:

Northern Forestry Centre
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Harvey, E.M., compiler. 1986. *Proceedings of the 1984 Prairie Federal-Provincial Nurserymen's Meeting*. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-274.

ABSTRACT

The 1984 annual meeting was held to exchange nursery information between nursery personnel and researchers from the prairie provinces. Papers were presented on nursery operations, nursery practice in British Columbia, equipment development, irrigation, cold hardiness, light quality, shelterbelts, and the Tree Nursery Weed Control Committee.

RESUME

Le but de l'assemblée annuelle était de permettre au personnel des pépinières dans les provinces des prairies et aux chercheurs d'échanger des informations. Les communications présentées ont porté sur les sujets suivants: les opérations en pépinières, les méthodes utilisées dans les pépinières en Colombie-Britannique, l'amélioration du matériel, l'irrigation, la résistance au froid, la qualité de l'éclairement, les rideaux abris, et le Tree Nursery Weed Control Committee (comité s'intéressant à la répression des mauvaises herbes en pépinières).

CONTENTS

	Page
1984 activities of Pineland Provincial Forest Nursery—Harold Tirschmann and Jim Atkinson	1
Clearwater Provincial Forest Nursery—Frank W. McKinney	3
Operations at Saskatchewan's four forest nurseries—John Thompson	5
Report on the 1984 activities at the PFRA Tree Nursery—G. Bruce Neill	7
Operations at Pine Ridge Forest Nursery—Rodger Hamilton	9
Operations at Blue Ridge Lumber greenhouses—Dale Currey and Daryl D'Amico	10
Whitecourt Mountain Seedling Nursery: the process, the plant—Barry Hutchinson	15
Prairie Sun Greenhouses' first-year experience with white spruce—John Murray	17
Forest nursery practice in British Columbia—Ralph F. Huber	19
Operational trials of a shrouded herbicide sprayer for weed control in forest nursery seedbeds—Jim Atkinson	26
Pine Ridge experience in greenhouse irrigation—Peter N. Au	28
Determining irrigation requirements of conifer seedlings—John Cruickshank	29
Conditioning containerized tree seedlings for cold tolerance—Ivor K. Edwards	32
Effects of light quality and photoperiod on twelve coniferous species—Ian J. Dymock and Sherry Wilson	34
Field shelterbelt investigations—Indian Head—John Kort	55
Formation of the Tree Nursery Weed Control Committee—Lyle K. Alspach	57
Attendees at the Prairie Federal-Provincial Nurserymen's Meeting	59

NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Canadian Forestry Service.

1984 ACTIVITIES OF PINELAND PROVINCIAL FOREST NURSERY

Harold Tirschmann and Jim Atkinson
Pineland Provincial Forest Nursery
Department of Natural Resources
Hadashville, Manitoba

PERSONNEL

No change in staffing of the nursery has occurred in the past several years; it at present consists of three permanent and eight departmental staff person-years in the following classifications: one Manager, one Nursery Superintendent, one Clerk, two Work Supervisors, one Welder, and five Operators. In addition, casual labor for the 1984–85 operating year will amount to approximately 17 staff person-years.

BARE-ROOT OPERATIONS

All bare-root stock at the Pineland nursery is spring lifted. Lifting operations this past spring commenced April 10 and were completed by May 3. A work force of 105 people was required during the peak period. The total bare-root stock shipped was 2 691 901 seedlings, and it consisted of the following species, ages, and amounts:

Jack pine	2–0	1 570 490
Scots pine	2–0	287 975
Red pine	3–0	592 225
Black spruce	3–0	2 720
Black spruce	2–0	47 050
White spruce	3–0	163 666
Siberian larch	2–0	27 775

Of the bare-root stock shipped, 93.5% went to the Department of Natural Resources, 4.6% went to the Provincial Tree Farm and Woodlot Programs, and 1.9% went to other agencies.

In the fall of 1983, extensive ditching was undertaken to improve drainage in the bare-root fields.

The winter of 1983–84 brought adequate snow cover, and subsequently no deer browsing or winter drying was experienced. Spring came early in 1984 and caused problems with early germination and ensuing damage from late spring frosts. Some 1–0 white spruce fields had already sustained heavy enough losses from frost heaving that they were plowed under and were spring sown.

Lophodermium needle cast disease continues to be in evidence, and all bare-root pine fields adjacent to shelterbelts containing red pine were sprayed with Manzate in several applications to minimize losses.

The bare-root inventory is near completion. All calculations have not been completed, but it is estimated that the inventory will total around 13 million seedlings. This total, combined with the projected fall seeding of 9 million seedlings, will provide an ongoing inventory of 22 million seedlings, which will be increased annually to bring the 1988 lifting to 10 million seedlings. The major species will continue to be jack pine, white spruce, and red pine.

CONTAINER OPERATIONS

The Pineland nursery has continued to produce two crops of containerized black spruce seedlings per year in FH408 paper pots. With the completion of two more greenhouses last February, a total of eight greenhouses were used to produce both crops.

The first crop germinated on February 8–16 and was moved into the shade houses on May 29 and 30. Shipping began July 18. This crop produced a total of 1 208 306 seedlings and had an average cull or empty cavity count of 4–6%.

The second crop was put into the greenhouses right on the heels of the first crop. It germinated June 5 and was moved into shade frame structures on August 13 and 15. This crop produced a total of 1 214 407 seedlings and had a 6% empty cavity count. We experienced problems with damping-off disease, grasshopper feeding, and physical damage possibly due to overheating of the grit used to cover the top of the plugs. Analysis of affected seedlings showed that the stems had collapsed, presumably from overheating.

This summer the Tree Improvement Section began sampling each greenhouse crop on a biweekly basis in order to compile data on growth characteristics. Stem diameter and dry mass of the shoot, root, and total are being recorded by greenhouse. This information will be

collated and used to graphically depict growth patterns at various stages of development. Eventually an ideal curve will be developed that will provide a meaningful standard toward which cultural practices will aim.

CONES AND SEEDS

The province's only seed extraction plant is located at the Pineland Provincial Forest Nursery, where all of the province's requirements for forest tree seed are processed during the winter months. Nineteen eighty-four has been a good seed year for white spruce, and to date we have received 107.25 hL of white spruce cones. In 1983–84 a total of 352.01 hL of cones were processed, yielding 166.694 kg of clean seed.

Conifer seed on hand in cold storage is as follows:

	(kg)
White spruce	159
Black spruce	140
Red pine	276
Jack pine	356
White pine	1
Scots pine	18
Siberian larch	8
Total	958

WELDING AND MECHANICAL SHOP

The nursery shop handles most repairs and modifications to nursery equipment and silvicultural pool equipment. Only work requiring specialized tools and expertise is farmed out to commercial shops.

RAINFALL

Rainfall to the end of August was 365 mm (14.37 inches), which is near the average for this time of year. The annual average rainfall during the previous 5-year period was 396.2 mm or 15.60 inches.

NURSERY EXPANSION

Nursery expansion to increase production from 4 million seedlings annually to 16 million seedlings annually (6 million container and 10 million bare-root seedlings) is progressing on schedule. The 16 million annual seedling production will be on stream in 1988.

Four new greenhouses are currently under construction. They are a double-inflated poly-type, and each unit consists of 270 m^2 of growing space. Eight shade structures have been completed this year, and four more will be completed before winter. These units consist of regular greenhouse steel covered with Parawebbing to provide approximately 50% shading or shelter from the elements. Each unit provides 520 m^2 of seedling growing space. The new metal seeding-line building has been completed this year, consisting of 167 m^2 of floor space. The new filling and seeding equipment will be installed in January 1985.

Development of four new bare-root fields has been completed to the seeding stage this year, and six additional large bare-root fields are under development and will be at the seeding stage for the fall of 1985.

NEW EQUIPMENT

The following new equipment was purchased this year:

one Honda 200 ATC
one riding lawn mower
one 1250 John Deere tractor
one Grayco lifter
one Oyjord bare-root seeder
one International 5-ton truck
one Case crawler tractor.

CLEARWATER PROVINCIAL FOREST NURSERY

F.W. McKinney
Clearwater Provincial Forest Nursery
The Pas, Manitoba

1983 CONSTRUCTION

During the 1983 construction year (April 1, 1983 to March 31, 1984), one headerhouse, one permanent shade frame, and three and one-half greenhouses were built.

1984 CONSTRUCTION

During the 1984 construction year (April 1, 1984 to March 31, 1985), the following construction is planned:

1. Five permanent shade frames (at time of writing, four have been completed by our Engineering and Construction Branch).

2. One headerhouse and six and one-half greenhouses. This will give us 12 operational greenhouses for the 1985 growing season. The construction of the six greenhouses and the finishing of the seventh has been tendered to a private company and to date three greenhouse walls and all six footings have been poured.

3. A lunchroom-bunkhouse. It will be tendered shortly. The building will be 24 × 46 feet, and will contain two bedrooms, two washrooms, complete kitchen facilities, and a large lunchroom area.

4. A seeding line-welding shop building. This will be an all-metal building, 40 × 300 feet, and will contain a welding-mechanical shop, an equipment storage area, a cone storage area, a seed extraction area, a seeding line area, and a washroom. This building will also be constructed by a private company.

5. Purchase and installation of the seeding line. This is to be done by our Engineering and Construction Branch.

6. A second pump house and pressure system for the second well. (The well is already drilled and capped.) This second well is designed to handle the water requirements for the seeding-line building although it will be looped to the existing system. This building is also well under way and should be completed in approximately 1 month.

7. Looping the water systems. The pump houses, complete with heat-traced utilidors, will be looped and valved so that:

   a) should one well break down, the other well system can be rerouted and can supply the water requirements for the greenhouses;

   b) should a waterline to any area break, it can be isolated, and water can be brought to the greenhouse from either or both systems.

   This project is to be completed by our Engineering and Construction Branch with a consulting firm. Whereas all water systems (underground lines) must be self-limiting, heat-traced utilidors, additional power supply stations will be required along the lines.

8. A second hydro line and transformer. These will be brought in and placed on the south end of the complex to provide electricity for the new facilities. Installation is to be by Manitoba Hydro.

9. A staff residence. It is one of two proposed for the complex and will be tendered for construction this fall.

1984 CROP

The 1984 crop consisted of 1 million black spruce and 200 000 jack pine. One greenhouse of the five in operation was started February 7, 1984, with over 200 000 black spruce, and the stock was moved to a shade frame on June 5. Frozen trays of jack pine were placed in the same greenhouse and were removed to the shade frame August 30. The remaining four greenhouses were started on or about March 22, 1984, as a single black spruce crop. Double-cropping in the one greenhouse was an experiment, not so much in the greenhouse stage, but at the time when the seedlings were put outside when there was still a danger of frost at the beginning and end of summer. We started the hardening process on the jack pine during their last week in the greenhouse, and

there has been no frost to date, so we should have no problems overwintering the stock.

There are, of course, added costs in starting the greenhouses in February. When the outside temperature was −38°C and the winds were 30 km/h, all three heating systems were used to maintain the required 18°C temperature. During a late March start-up, however, only the wood furnace and minimal backup electric heat is required. The wood furnace is rated at 500 000 Btu, the electric furnace at 250 000 Btu, and the propane furnace at 250 000 Btu.

1985 PLANNED PRODUCTION

In 1985, we are planning to produce 2 million black spruce, 400 000 white spruce, and 400 000 jack pine. Two greenhouses will be double-cropped in 1985, one with jack pine and one with black spruce.

1985 PLANNED CONSTRUCTION

One headerhouse, four greenhouses, and four shade frames will be constructed in 1985. More work will be done on the seed extraction, seed storage, and welding-mechanical shop areas.

OPERATIONS AT SASKATCHEWAN'S FOUR FOREST NURSERIES

John Thompson
Department of Parks and Renewable Resources
Prince Albert, Saskatchewan

Saskatchewan has four forest nurseries; two of these are large nurseries and two are satellite nurseries. The larger nurseries each produce in excess of 4 million bare-root seedlings annually, and the satellites produce about 1 million trees annually. The nurseries are all located within 200 km of Prince Albert, the administrative center for forestry in Saskatchewan.

PRINCE ALBERT FOREST NURSERY

This nursery has both bare-root and container growing capacity, although containers were used only marginally last year to grow experimental (provenance) stock. In 1983, this nursery produced 7 299 961 trees for distribution, and of these, 92.7% (6.77 million) were for reforestation purposes. The balance were grown for woodlots and for ornamental and aesthetic purposes for parks, schools, and churches. White spruce bare-root stock was the primary reforestation species shipped; 936 000 bare-root and 773 000 jack pine containers were shipped. There were 403 836 trees and shrubs lifted for fall planting programs and for overwinter storage for minor distribution to parks, campgrounds, and woodlots.

I mentioned that only a small crop of containers were grown. It is likely that the greenhouses will continue to be underutilized until at least 1986. Future developments will see full use of the greenhouses; discussions will be held with Prince Albert Pulp Company concerning growing their improved seed from their tree improvement program. Also, it is anticipated that after the Saskatchewan government signs Forest Management License Agreements (FMLA's) with private companies, the greenhouses and our other facilities will be fully utilized.

Cone collection in 1983 was not very successful. White spruce did not produce a crop, and squirrels were not cutting many jack pine cones (yes, we still raid squirrel caches). We collected a total of 356.56 hL of cones, which yielded 199.6 kg of seed, or 201 g of seed per hectolitre. We paid $30.00 per hectolitre, and our extraction costs were $355.82 per kilogram of clean seed. The cost of producing bare-root stock, including labor, material, land maintenance, and indirect costs (depreciation, etc.) was $78.34 per thousand for 3–0 stock and $52.96 per thousand for 2–0 stock.

BIG RIVER FOREST NURSERY

Big River Forest Nursery produces primarily white spruce and jack pine bare-root stock; white spruce is shipped as 3–0 stock and jack pine as 2–0 stock. The nursery also has a small poly-greenhouse capable of growing 150 000 per crop. The greenhouse is not in use at present. Last year, Big River produced 4 057 000 bare-root and container stock. White spruce made up 75% of the crop, with the remainder being jack pine and other conifer species.

No fall lifting took place in 1983. Big River acquired two new pieces of equipment last year, namely, a Love-Oyjord seeder and a Fobro lifter. The Fobro has performed very well in the heavier soils at the nursery. All seedlings are manually removed from the soil and placed in galvanized tubs.

Big River costs for producing bare-root 3–0 conifer seedlings, including lifting and packing, are $76.12 per thousand, and the costs for producing 2–0 seedlings are $60.06 per thousand.

SOUTH BRANCH FOREST NURSERY

South Branch Forest Nursery, a small satellite south of Prince Albert, produced a total of 869 814 trees in 1983. Of these, 97% were for reforestation, and the balance were for minor uses such as woodlots and parks. South Branch produces only bare-root stock because it has no greenhouses. The nursery also produces large balled or potted stock using a Jiffy Baller for park areas requiring stock that won't fall prey to lawn mowers. Species shipped include hybrid poplars, willows, and other hardwoods, and conifers such as white spruce and Siberian larch. This potting program has met an important demand and will be continued.

In 1983, 800 potted trees were shipped from South Branch Forest Nursery. The potted trees cost $6.86 each

Conifer Inventory November 1983

Species and age	Prince Albert Forest Nursery	Big River Forest Nursery	Chitek Lake Forest Nursery	South Branch Forest Nursery	Total
White spruce					
1-0	8 839 168	8 375 500	826 800	690 393	18 731 861
2-0	6 759 406	7 541 200	—	1 412 711	15 713 317
3-0	3 558 673	3 450 100	—	—	7 008 773
4-0	2 180 494	—	355 760	180 125	2 716 379
Total white spruce	21 337 741	19 366 800	1 182 560	2 283 229	44 170 330
Jack pine					
1-0	4 552 254	—	—	—	4 552 254
2-0	5 195 471	—	3 830 446	—	9 025 917
Total jack pine	9 747 725	—	3 830 446	—	13 578 171

to lift and produce; for bare-root the costs were $132.40 per thousand for 4-0 stock.

In the future, this nursery will also serve as a tree breeding research station. A site has been cleaned for a jack pine seed orchard (based on Dr. J. Klein's jack pine breeding program), and some breeding work will be done with white spruce super seedlings.

CHITEK LAKE FOREST NURSERY

Chitek Lake Forest Nursery is located about 200 km northwest of Prince Albert. It produces bare-root conifer potted stock. In the fall of 1983 the nursery lifted a total of 212 500 white spruce for reforestation purposes. Spring activities were devoted to the lifting of 800 potted trees for provincial parks. The cost per potted tree was $5.70, and the cost for bare-root reforestation stock was $111.66 per thousand.

In closing, I'll give a glimpse into the future. Saskatchewan has recently signed a federal-provincial agreement for forestry development. This agreement identifies funding for nursery capital development at Big River and Prince Albert nurseries. Development is currently in its preliminary stages. The capital development will include new pump houses for both nurseries, a packing and cold storage building for Big River, and a staff facility for Prince Albert.

REPORT ON THE 1984 ACTIVITIES AT THE PFRA TREE NURSERY

G.B. Neill
PFRA Tree Nursery
Indian Head, Saskatchewan

The PFRA Tree Nursery supplies seedling trees to prairie farmers for use in farmyard shelterbelts, field windbreaks, and roadside belts. Nursery staff are divided into four groups, namely, Administration, Production, Distribution, and Investigations. The following is a brief update on developments at the nursery this past year.

NEW CONSTRUCTION

The Administration and Distribution sections were recently moved to the nursery site into a new office building. Our old administration building, located in the town of Indian Head, will be put up for public tender. The new location should make for improved communications between sections and allow for a reduction in staff.

The old cold storage rooms have been convertec into an underground greenhouse for production of container-grown Siberian larch. The rooms have been equipped with high-pressure sodium lights and a small gas furnace. We are trying this approach rather than our regular greenhouse in an effort to lower energy costs.

Our Investigations greenhouse has also undergone modification, with the addition of 6 inches of fiberglass insulation between metal studs and a cover of metal sheeting. This covering has been applied to the north walls, north ceiling, and west end.

NEW STAFF

Notable additions to our nursery in the past year are Debbie Rink, Wayne Holzapfel, and John Kort. Debbie works as a Distribution Technician, and she comes to us from the grounds department of the RCMP depot in Regina. She has a Bachelor's degree in Horticulture from the University of Saskatchewan. Wayne is our Gardener, and he comes to us from the grounds section of the Agriculture Canada Experimental Farm at Indian Head. He also has a Bachelor's degree in Horticulture from the University of Saskatchewan. John Kort is our new Shelterbelt Biologist and is studying the effect of shelterbelts on soils and crops. John has a Master's degree in Horticulture from the University of Manitoba.

DISTRIBUTION ACTIVITIES

During the spring of 1984, the tree nursery distributed approximately 6.3 million trees to 10 333 tree planters. Again, caragana was the shrub in greatest demand (42% of total tree distribution). Green ash was the deciduous tree in greatest demand (9.8% of total tree distribution), and Colorado spruce was the conifer in greatest demand (5% of total tree distribution). Approximately 58% of the trees distributed were used in farmstead shelterbelts, and 15.7% were used in field and roadside belts.

Distribution in 1983 and 1984

	1984	1983
	(000's)	
Deciduous shrubs	3 805	3 895
Deciduous trees	1 925	2 207
Coniferous trees	571	568
Number of applicants serviced	10 333	10 900
Field belts (km)	591	732
Roadside belts (km)	41	46

Applications are accepted starting June 1 of each year for tree shipment the following spring. They are serviced on a first-come-first-serve basis until February 14, the deadline for accepting applications.

DEVELOPMENT

At present, we are still conducting our preplanting planning assistance visits. By mid-October, approximately 775 farmers will have been visited by technical staff and provided with recommendations on shelterbelt design, species, maintenance, and rejuvenation, and on other tree-related problems and concerns.

Major field shelterbelt projects are underway in the Crystal Lake (Canora) area in Saskatchewan and in the Niverville and Winkler areas of Manitoba. In the spring of 1984, approximately 50 km of field shelterbelts were planted in these projects by nursery personnel. Plans for

spring 1985 include about 60 farmers and 100 km in the Crystal Lake and Winkler projects and about 4 farmers and 8 km in the Niverville project. There has been a strong interest in soil conservation programs, including the planting of field shelterbelts, so an increased demand for tree nursery technical assistance and involvement is expected.

Short courses, displays at agricultural exhibitions, slide presentations, television and radio interviews, news releases, and brochures are used to disseminate information regarding shelterbelt planning and maintenance.

INVESTIGATION ACTIVITIES

A variety of projects were conducted by the five units of the Investigations section during the past year.

The Propagation unit has been working on tree selection of ponderosa pine, Scots pine, Siberian larch, poplar, green ash, and willow. Studies have also been conducted on refrigerated storage of conifer seedlings, seed storage and germination of hawthorn and honeysuckle, and container production of Siberian larch.

The Entomology-Pathology unit has been testing fungicides for control of storage molds and pheromones for monitoring spring cankerworm, carpenterworm, and cottonwood crown borer. The main pests of the season were cottonwood leaf beetles, willow shoot borers, and spruce spider mites. The Saskatchewan Dutch Elm Disease Survey was headquartered at the nursery, and no new cases of DED were found in the province in 1984.

The Soils unit has been doing irrigation scheduling trials in conifer transplants and has been monitoring and mapping salinity of the nursery soils.

The Herbicide unit conducted a number of screening trials on conifer and deciduous sowings. A major undertaking this past summer was the hosting of an International Nursery Herbicide Workshop. Proceedings from this workshop will be distributed shortly.

The Shelterbelt Studies unit was initiated in June 1984 with the hiring of John Kort. We look forward to studies on the effects of shelterbelts on prairie soils and crops.

Summaries of all activities will be reported in our next edition of the PFRA Tree Nursery Annual Report. Please write to the following address if you wish to be placed on our mailing list:

Dr. J.A.G. Howe
Superintendent
PFRA Tree Nursery
Indian Head, Saskatchewan
S0G 2K0

OPERATIONS AT PINE RIDGE FOREST NURSERY

Rodger Hamilton
Pine Ridge Forest Nursery
Smoky Lake, Alberta

The 1983–84 season at Pine Ridge saw some reduction in crop size of container seedlings, reduced sowing in the bare-root program, but a busy year in the seed program.

CONTAINER PROGRAM

In 1984, the March seeding was for 10.9 million seedlings, and the June seeding was for 2 million seedlings. The 1983–84 winter caused some problems as there was a severe frost in early September that our shade frames' frost irrigation was unable to handle. This, combined with a January thaw and rain, caused a 15% overwintering loss.

BARE-ROOT PROGRAM

In the fall of 1983, 7.3 million trees were lifted. Our stock currently consists of the following:

3–0—16 902 000, to be lifted fall 1984
2–0—14 000 000
1–0—10 127 000

All of the bare-root pine is lifted as 2–0 stock.

The nursery is going to a large production scale bare-root hot-lift this fall. We expect to lift 1.8 million trees during August and September for immediate replanting in the forest. Lifting commences at 5:30 a.m., and truck loads of sorted and packaged trees are departing for the forest by 9:00 a.m. Our objective is to have the trees replanted no later than 96 hours after lifting.

The nursery has developed underground cold storage units that depend upon passive refrigeration. Squash culverts were buried under 1.4 metres of soil. Culverts are 8 feet high, 13 feet wide, and 70 feet long. In January and February last winter the doors were opened and the whole mass was allowed to become supercooled. The bottoms of the culverts were then flooded with water until 1 foot of ice was built up. The double air-lock doors were then closed. Experimental storage of bare-root to date has shown that frozen trees kept at −2°C are in excellent condition for outplanting.

SEED PROGRAM

There was a heavy spruce crop across central and northern Alberta in the summer of 1983. The government forests and forest industries picked 11 323 hL of white spruce. An additional 14 007 hL of pine were also collected. The seed extraction and cleaning plant ran from the 1st week of November to the end of the 2nd week in March. During this time, we extracted and cleaned 13 895 kg of white spruce seed and 1 388 kg of lodgepole pine seed.

Approximately 8 774.79 kg of white spruce and 1 609.34 kg of lodgepole pine seed were withdrawn from September 1, 1983, to August 31, 1984, for nursery sowing and aerial seeding.

SHIPPING

By the end of this shipping season we expect to have shipped 9 129 000 bare-root and 14 216 000 container trees for a total of 23 345 000 trees.

The nursery shipped its one-hundred millionth tree this past year. A small ceremony and symbolic tree planting was held at the nursery to commemorate the event.

OPERATIONS AT BLUE RIDGE LUMBER GREENHOUSES

D. Currey and D. D'Amico
Blue Ridge Lumber Greenhouses
Whitecourt, Alberta

INTRODUCTION

Our company is a relative newcomer to the province. Our Blue Ridge story begins in 1974, when the province of Alberta announced it had selected Simpson Timber Co. to develop and operate a forest products complex to utilize small-diameter timber on approximately 1.2 million acres of the Whitecourt Forest. A 20-year renewable Forest Management Agreement (FMA) formalizing the award was signed December 3, 1975.

The Forest Management Agreement was developed cooperatively and is designed to suit particular needs. A unique part of the agreement was provision for up to 40% ownership by Albertans. This joint venture was formed in June 1976 with the Alberta Energy Company Ltd. acquiring 40% of the assets of Simpson Timber Co. (Alberta) Ltd. Alberta Energy Company Ltd. (AEC) was established in 1975 as a public company to provide Albertans with an opportunity to participate in the development of Alberta's energy and natural resource potential. Simpson Timber became 100% owned by AEC when the remaining 60% of the assets were purchased in June 1981, and a resource company called Blue Ridge Lumber (1981) Ltd. was established effective January 4, 1982.

The Forest Management Agreement is an area agreement that gives the company the right to harvest all of the timber that can be grown annually. The agreement area is designated primarily for the planning, managing, growing, and harvesting of timber. The company is dedicated to follow sound forestry practices, with the objective of achieving a perpetual sustained yield of timber from the productive forest land. All FMA holders in the province have reforestation responsibilities and must carry out a program that ensures Alberta Forest Service regeneration standards are met. As part of the operations under the agreement, the company is required to construct and operate a tree nursery to furnish all of the seedlings required to reforest areas harvested by the company.

Blue Ridge Lumber manages approximately 1 760 square miles or 1 125 000 acres or 450 000 hectares of spruce, pine, fir, and aspen forests in central Alberta and logs 100 million board feet or 160 000 cunits. For people already thinking in metric, that equals 450 000 m^3 of mature and overmature timber from that area annually.

The company also operates under quota licenses. In this instance, the Alberta Forest Service takes on the forest management responsibilities, determines the amount of timber to be cut, and issues a license to each quota holder that outlines the area in which logging is permitted. Quota holders, because they are generally smaller, family-type operations that do not always have the forestry technical knowledge available, are given an option that enables them to either conduct their own reforestation program or pay a reforestation charge of $7.00 per thousand board feet to the province.

In 1975 the company itself became a quota holder when it purchased the quota cutting rights from a few sawmills around Whitecourt. In addition to the timber that Blue Ridge Lumber is logging from its FMA, the company also logs 4.6 million board feet or 19 740 m^3 per year of quota timber in the Slave Lake Forest and 28.6 million board feet or 122 750 m^3 in the Fox Creek area of the Whitecourt Forest.

Under both the quota and Forest Management Agreement approximately 6 500 acres of timber area are harvested annually to supply the 130 million board feet of timber required for the Blue Ridge mill. These 6 500 acres represent a total of over 10 sections of timber harvested annually.

Each acre harvested by the company must be reforested to an acceptable provincial stocking standard within 7 years. The main objective of reforesting company cutover areas is to prepare the site, such as by scarification, for both artificial and, wherever possible, natural seeding. Another company objective of reforesting cutover areas is to improve on nature through silviculture to produce a more productive and useful forest than nature can and to do so in far less time. This means bringing forests from an unmanaged state to a managed state to ensure that they produce more timber in the second rotation than they did in the first. The first step in improving on nature is to ensure seedling establishment and correct spacing through planting.

NURSERY OPERATION

In order to meet reforestation requirements and to reforest cutovers that do not regenerate naturally, the company decided to construct a containerized nursery in 1976, which was earlier than initially anticipated. The decision was strengthened by the fact that, with the purchase of the cutting rights from quota holders in 1975, the company assumed reforestation responsibilities on over 11 400 acres of cutover lands. The expectation was that half of those acreages would be non-sufficiently regenerated and against the legal deadline for regeneration. The company had to treat approximately 5 000 acres in the shortest time possible in order to meet legal deadlines. All of those acreages would have to be scarified and planted, and would require 2.5 million seedlings in the following few years. Because these seedlings were required for planting in quota areas, the province should have made seedlings available free of charge. The Alberta Forest Service, however, was not able to meet its obligations to quota holders, and it was even suggested that the company should institute a crash program of lifting and planting of wildings. Contractors and tree nurseries were approached, but nobody seemed to be interested in growing seedlings for the company at a reasonable price.

In March 1976 the company commenced the construction of a $170,000 nursery to produce 800 000 containerized seedlings a year to meet seedling requirements for quota reforestation, in addition to seedlings supplied by the provincial tree nursery. The Blue Ridge Tree Nursery was officially opened in September 1976.

The greenhouse (42 ft., 2 in. × 156 ft., 8 in., or 6 600 sq. ft.) is an Arch II fiber glass greenhouse, delivered and erected by Ickes Braun Glasshouses of Canada.

The main species considered for nursery production were white spruce and lodgepole pine. The objective was to produce two crops a year. The first crop of 300 000 white spruce and 100 000 lodgepole pine seedlings was started from seed early in February 1977. The seedlings left the greenhouse when they were 3–5 inches in height and were hardened-off and ready for planting by the end of May. The crop was planted out in the cutover areas in June of the same year. A second crop of 400 000 white spruce seedlings was started in June 1977 and left the greenhouse hardened-off in September of the same year. The seedlings were placed outside in cold frames for overwintering under a protective cover of snow. That second crop was planted in the summer of 1978.

The interior layout of the greenhouse can be described as follows. Polypropylene trays (14½ × 8½ × 4 in.) containing 102 seedlings growing in Spencer-Lemaire containers stand in 7½ × 2½ foot pallets. These pallets stand on racks, keeping the seedlings at a convenient working height of 2½ feet. Each pallet can contain 20 trays or 2 000 seedlings. The pallets have open bottoms, and the racks keep the pallets off the ground. This allows air to flow underneath the trays holding the containers, which is important to prevent clogging with roots. The pallet racks in the greenhouse are long enough so that thinning can be done by separating the pallets. A 6-foot wide aisle runs lengthwise down the center of the greenhouse. At both sides of the aisle there are two serried rows of pallets.

Environmental factors to be controlled within this greenhouse are root-zone moisture, plant nutrients, temperature, and light. Root-zone moisture is controlled by a traveling overhead sprinkler and lighting system designed by a local contractor. The system is very simple. The basic feature of the system is a gantry made of 3 × 1½ × 3/16 inch channel iron with a dimension of 26 × 6 feet that travels the length of the greenhouse to spray down the seedlings or to lengthen the photoperiod by applying intermittent lighting. The gantry is pulled by a cable. This cable is wrapped around a steel drum (1 foot in diameter), which is driven by a one-half horsepower, three-phase motor. The cable runs over six pulleys, which are 12 inches in diameter (two on the roof and two on each end of the greenhouse). When the gantry reaches one end of the track, a limit switch will cause the electric motor to reverse its rotation, resulting in the drum also reversing its rotation; this causes the gantry to be pulled back to the other end of the greenhouse. The gantry is suspended 4 inches with eyebolts from ball-bearing roller wheels in three bond door iron tracks, allowing lengthwise travel through the greenhouse. By suspending the gantry from a loose-pin mounting, the entire system is more flexible in case of building shift or improperly aligned tracks. The tracks are welded to bottom chords of the arch-shaped roof of the greenhouse. A hose supplies water to the gantry from a water tap in the corner of the greenhouse. The hose is connected to a 2-inch steel pipe attached to the gantry and hangs in loops from a separate track, which allows the hose to travel back and forth with the gantry. Eight ¾-inch PVC dropper pipes, with a sprayer at one end, are screwed in the 2-inch steel pipe at 3-foot intervals.

Lighting for photoperiod control is supplied by eight 400-watt, high-pressure sodium lamps installed on the traveling gantry approximately 6 feet above the top of the

containerized seedlings. The travel speed of the gantry of 9 feet per minute is regulated so that the seedlings receive a total of 2 minutes of light every 30 minutes during the dark period. Recent research work in Canada has proved that intermittent light has the same effect as constant light, provided that the intensity of the light is sufficiently high. Our seedlings receive light at the top with an intensity of 500 footcandles.

Power is supplied to the gantry by a festoon electrical cable system. The high-pressure sodium lamp was chosen because it provides higher light intensity with optimum spectral composition for photosynthesis. The maximum quantum yield for photosynthesis is attained at two broad spectral peaks centered at 620 nm (the red wavelength) and 440 nm (the blue wavelength). The high-pressure sodium lamp has the correct light composition.

Summertime cooling is provided by three IBG Coolair exhaust fans with 48-inch diameter blades and a 1-horsepower motor at one gable end, which draws air through evaporative cooling pads, 8 feet high, at the other end of the greenhouse. During hot summer days the capacity of this cooling system is still not adequate. This makes it necessary to draw black polypropylene shade cloth (47% actual shade) over the roof of the greenhouse to reduce solar heat penetration into the greenhouse.

The greenhouse is heated by six Modine gas-fired, propeller heaters. Total input for each unit is 300 000 Btu per hour. The heaters are installed between the trusses and the bottom chord of the roof. Two IBG Fact impeller intake vents, installed in one gable end, force air into polytubes perforated by equally spaced holes facing downward. The air blowing downward through these holes also forces any hot air pocketing against the greenhouse ceiling to flow downward. In this way, a more equal temperature differentiation is obtained.

Plant nutrients are dissolved in water and injected into the water system by a Smith Measuremix fertilizer injector in an accurately controlled proportion of 1:200 as water passes through the machine. This injector operates on water power according to the Venturi principle and requires no electric motor or gasoline engine.

The containers primarily used for seedling production are the Ferdinand Rootrainers, produced by Spencer-Lemaire Industries in Edmonton. Rootrainers are thermo-formed sheet plastic folding pots that are held together in a standard box or tray. When folded, multiple deep cavities are formed that can be filled with a growing medium. Their features include grooves that prevent the roots from spiraling and a slip-lap seal that prevents roots wandering from cavity to cavity. Rootrainers are packed in nested stacks in the open position. The Ferdinand has six cavities, each 2.5 $in.^3$ or 40 mL. Rootrainers are folded up like books and set into the trays, where their grooves hold them steady against side movement. Seventeen Ferdinand Rootrainers fit into a tray. The work of folding Rootrainers and assembling trays is contracted out by the company to interested local community organizations or service clubs. The contractor is paid by the tray, which is assembled and filled with the 17 Rootrainers. The Rootrainers are not reused after a cycle, but the trays can be reused at least three times. They should be washed and sterilized with Javex before reuse.

The growing medium used by Simpson's nursery is sphagnum peat moss. Peat moss has the following desirable physical characteristics:

1. a good water-holding capacity;

2. a good cation exchange capacity, which controls the retention of nutrients in an exchangeable form, and;

3. a good pH of 4.5–5.5, which is excellent for a rooting medium of coniferous species. We are using straight peat moss. No mixing with Terra-Lite or vermiculite is done, because it hampers the drainage of the peat moss growing medium. The peat moss should be moistened prior to filling the Rootrainers. If not moistened, the peat moss is extremely difficult to soak by sprinkling with water. The moisture content of the moss should be in the range of 80–85% by weight.

Mixing of the dry peat moss with water and the filling of the Rootrainers occurs in the filling machine, which is designed by Coutts Machinery by order of Spencer-Lemaire Industries in Edmonton. In the filling machine, a motor-driven auger mixes the peat moss with water and a soil wetting agent in a big steel-plate trough, or mixer. A bucket elevator lifts the dampened peat moss out of the mixer to a discharge height of 6 feet and spreads the moss over six trays filled with empty Rootrainers. The trays are then clamped to a steel shaker table, which shakes the peat down into the Rootrainers. The table can also be slammed up and down to get the right compaction of the rooting medium. Excess peat moss falls back through the gauzed bottom of the table and over the edge back into the mixer underneath the shaker table. The machine is controlled by three push

buttons and a foot pedal for the slammer and can be handled by one person and a helper who assists in filling the machine with peat moss. This filling of the containers and the seedlings is all done in the headerhouse.

After the containers are filled with moist peat moss, seeds are placed in each cavity. Germination tests with the seed to be used are necessary prior to seeding in order to assess the amount of seed to be placed in a cavity. This ensures that there is at least one germinated seedling in each cavity.

To increase germinative capacity and energy, we apply a preseeding treatment such as cold stratification, which is a cheap, yet effective, method to break seed dormancy. The seed is soaked in normal temperature tap water for 24 hours. The empty and half-empty seed that is still floating is discarded, while the viable, full seed sinks to the bottom. This good seed is stored moist in plastic bags in a refrigerator at 4°C for 4 weeks. The seed should be dried at room temperature when taken out of the refrigerator, and it should be seeded as soon as possible. The response to this cold stratification is remarkable, especially of lodgepole pine seed, and a uniform crop is obtained.

At present, seeding is done by hand. We are using small hand-seeders that contain up to 1 ounce of seed, which is released through a small hole either singly or several at a time. We are continuing to investigate the application of suitable mechanical seeders.

The seeds in the containers are then covered by hand with number 2 granite grit, and the trays are placed in the pallets. Stacks of pallets are brought into the greenhouse by a forklift. The trays are then watered lightly to bring the seeds into contact with the medium.

After watering, the trays are covered with 4-mil plastic in winter or with burlap cloth in summer. This covering is necessary to prevent the loss of moisture from the peat and to increase the temperature slightly during germination. The length of time the covering is left on depends on the species, but it is removed when germination begins. For white spruce it is usually removed after 10–12 days, and for lodgepole pine it is removed after 6–8 days.

During germination, and during the 6 weeks after germination, day and night temperatures are kept constant at 21-24°C. In the 7th week, the day temperature is reduced to 18°C and the night temperature to 15°C. These temperatures are maintained until hardening-off.

The intermittent lighting of 2 minutes each half hour during the dark period is applied as soon as the plastic or burlap cover is removed and is maintained until hardening-off. During midsummer (June and July), no additional lighting is applied during the dark period.

Acidified water is applied three times per week for 2 weeks after germination. In the 3rd week, watering is reduced to twice a week, and liquid fertilizer is injected into the watering system. The first watering in the week, when the fertilizer is added, should be heavy, and the growing medium should be saturated to allow excess salts from the previous fertilization to flush out. After each application of fertilizer, the fertilizer solution is rinsed off the needles by sprinkling with clean water for about 20 seconds. The second watering in the week is only applied if necessary and is a light watering with clean or acidified water. As the pH of our nursery water is 7.2, we have to inject a sulfuric acid solution into our water system to bring the pH down to 5, which is more desirable for the growth of coniferous seedlings.

The fertilizer regime we are applying has been set up for us by the Northern Forestry Centre of the Canadian Forestry Service in Edmonton. This regime takes into account that between weeks 3–10 the seedlings require a regular supply of N-P-K, with the N and K making up the major portion. This is the period of rapid growth that can be maintained by proper light and temperature and a continued supply of N-P-K. Minor or trace elements are also needed to enhance growth and structural development. Most commercial fertilizers also contain a full complement of minor elements.

Our nutrient prescription for the first 10–12 weeks, using commercial fertilizers, is made by dissolving in 1 gallon of water 460 g of 20–20–20, 110 g of 20–5–30, 74 g of 0–0–62 (white water soluble form), and 50 g of Fe 330 chelate (10% Fe).

This stock solution will be diluted 200 times by injection into the water system at a ratio of 1:200. The strength of the feed solution in parts per million is then 125 N, 47 P, 156 K, and 5.5 Fe.

Three weeks after the removal of the plastic or burlap cover, the seedlings are thinned to one per cavity to maximize the effect of container volume and nutrient regime. Thinning is unfortunately a hand operation and is very time-consuming. It requires the ability to recognize vigorous seedlings. Excess germinants are pulled out with tweezers.

After 10–12 weeks of rapid growth, the artificial hardening regime will be introduced. This hardening will still take place in the greenhouse. The hardening process promotes tolerance to adverse conditions encountered after planting, such as frost, draught, and sunscalding. It stimulates the transition from active shoot elongation to dormancy induction of the seedlings, during which process terminal buds are initiated and developed. We are trying to achieve dormancy induction of the seedlings by moderating the moisture stress; watering is reduced to only once a week, and there is no additional lighting, thereby reducing the daily photoperiod. We also lower the nitrogen content of the nutrient solution and adapt the temperature to natural conditions, while keeping it above freezing. The nutrient solution to be used now will mainly promote root development. The solution is made by dissolving in 1 gallon of water 400 g of 10–52–10, 200 g of 0–0–62 (white water soluble form), and 50 g of Fe 330 chelate (10% Fe).

This stock solution should be diluted 200 times, and the strength of the feed solution in parts per million is then 44 N, 101 P, 150 K, and 5.5 Fe. Iron is added because it is important in the synthesis of chlorophyll. The main component in this nutrient solution is phosphate. This hardening process is maintained for 3 weeks, after which the seedlings will be ready for planting.

The second crop leaving the greenhouse by the middle of August will remain outside in the cold frames for overwintering under a cover of snow. It is important to place the trays on a layer of sand and to not allow any air flow underneath the trays during the winter, otherwise the root system of the seedlings will be damaged by freezing and desiccation (drying). The seedlings outside in the cold frames require only watering and fertilizing (the hardening-off fertilizer regime) until frost sets in. During the first 3 weeks that the seedlings are outside in the cold frames, they require screening from early night frost.

CONCLUSION

The Blue Ridge nursery is currently capable of producing two crops of trees, totaling over 1 million seedlings annually. This capability far exceeds the company's present annual requirements for approximately 200 000–300 000 seedlings.

There are four main reasons for the sharp decrease in the company's seedling requirements over the past several years:

1. The company has successfully completed the backlog of quota reforestation obligations.

2. The company has pioneered improved site treatment techniques such as ripper scarification, direct seeding, and natural regeneration, thereby reducing planting considerably.

3. With the opening of the new provincial tree nursery at Smoky Lake, the province can now supply all the seedlings required by quota holders, including our company. Quota holders obtain the seedlings for quota reforestation free of charge from the province.

4. Better-quality regeneration surveys now assure that acres are not treated unnecessarily. Significantly fewer non-stocked regenerating areas now require planting than was originally calculated in 1975 and 1976.

In order to solve the problem of utilizing the capacity of the nursery, the company tried successfully to sell its surplus seedlings and discovered an open market for container seedling sales in the province.

Ornamental stock such as Colorado blue spruce, lilac, elm, Norway spruce, Scots pine, mugo pine, birch, and maple are grown for tree farmers, acreage owners, and homeowners for landscaping, Christmas tree and ornamental plantations, and shelterbelts, and for starter stock for other nurseries.

Recently, seedling sale contracts have been made to supply seedlings to other FMA holders and several coal and petroleum companies.

WHITECOURT MOUNTAIN SEEDLING NURSERY: THE PROCESS, THE PLANT

Barry Hutchinson
Whitecourt Mountain Seedling Nursery
Whitecourt, Alberta

Whitecourt Mountain Seedling Nursery is a privately owned nursery operation dedicated to growing tree seedlings for forest reclamation in Alberta.

At present, Whitecourt Mountain Seedling Nursery has an annual production capacity of 2.4 million seedlings; 1.2 million are grown annually in greenhouses, and 0.2 million are grown in continental climate transplant beds. The balance finish as 2–0 stock in a growing area.

All stock is started in containers in the greenhouses. The 28 000 square feet of greenhouse space is covered by gutter-connected, double polyethylene. This area is heated by nine 400 000 Btu/h furnaces. The rolling bench system, consisting of flat wire platforms that hold the containers, provides maximum use of the greenhouse growing area, yielding 85% growing space. Each bench can be loaded with seeded containers at a central station and pushed along a track to its growing area. There it stays until the time comes for extraction, and then the process is reversed. The benches are rolled back to the central station and unloaded; the seedlings are extracted, packaged, and packed into cardboard boxes for delivery or storage. Some containers are unloaded and moved into the holding yard to harden-off before delivery.

The holding yard is 80 × 500 feet. The irrigation system servicing this area is equipped with fertilizer injection, which continues to nourish the seedlings. A second year's growth in the holding yard yields a stronger seedling of a larger size that is more resilient in severe climatic conditions.

New plant production begins when the containers, 6-inch high Styrofoam blocks with 150 cavities each, are seeded in the last week of February and later. A growing medium of peat moss and vermiculite is poured into the cavities, two or three seeds are placed on the medium in each cavity, and washed aggregate (fine gravel) is placed on top. The blocks are then placed on the benches and rolled into position in the greenhouse for germination. In this early stage the cavities are sprayed with water twice a day. Once germination occurs, the crop is thinned to one seedling per cavity.

The water supplied to the greenhouse to nourish the plants follows a closely monitored route. Water is pumped into a holding tank from either a nearby dugout or a well, depending on the season. Once the water reaches the holding tank, it is circulated through 12 solar panels, where it is heated and returned to the holding tank for testing pH balance. The water is tested twice daily for prescribed fertilizer requirements. Each stage of the plant's development has its own nutrient requirement. To ensure that the nutrient solution is correct, the water is tested in our small laboratory before each application. Once the prescribed fertilizers have been injected into the irrigation water, the water moves into the greenhouses and is sprayed over the crop by moving overhead booms.

When the crop nears target size in late July or early August, the roof of the greenhouse is removed to expose the plants to natural weather conditions. Maintenance is then continued under ½-inch wire mesh netting to prevent hail damage. Some clients prefer to have their crop fully exposed to all weather conditions; these seedlings are removed from their containers and are transplanted into field beds for a heavier root system. Six acres of field has been prepared for the transplant stock. Water for irrigation is provided by a dugout. Fertilizer is applied by liquid feed.

When freeze-up appears imminent, the remaining trees in the greenhouse are extracted from their cavities, wrapped in bundles of 25, packed in boxes, and held in a root house storage area over winter. Undersized stock will be consolidated and will remain in the cavities. The blocks of undersized trees are then removed to the holding yard until the following growing season. They are nurtured in the holding yard by the irrigation system and are brought up to size the following spring.

When growing tree seedlings, especially white spruce, the following factors must be taken into account when nurturing the crop: market size, height, caliper, and root mass; lighting, to shorten the night to prevent dormancy; and carbon dioxide, to enhance root development by 20%.

WHITECOURT MOUNTAIN SEEDLING NURSERY

	Biogeoclimatic and soil data
Location	Latitude 54°4'N Longitude 115°40'W
Elevation	800 m
Total annual precipitation	530 mm
May to September	339 mm
Mean daily temperature May to September	11°C
Average frost-free days (June 19 to August 23)	70
Soil	
Soil group	Gray wooded
Parent material	Sandy alluvial Lacustrine clays
Texture (top 20 cm)	
Silt	35%
Sand	40%
Clay	25%
pH	6
Electrical conductivity	0.3 mS/cm
Organic matter	3%
Cation exchange capacity	25 meq/(100 g)

The purpose of this intensive operation is to produce a superior seedling that is stress resistant. Standby power and alarm systems help us keep watch over our crop and prevent any serious damage from a power failure or a severe drop in temperature. They also help us honor the performance bonds our customers have with the inspecting agencies.

Whitecourt Mountain Seedling Nursery operates with a permanent staff of two people and an auxiliary staff of 10 people. During the various peaks in the crop cycle 50 more people are called in to assist.

PRAIRIE SUN GREENHOUSES' FIRST-YEAR EXPERIENCE WITH WHITE SPRUCE

John Murray
Prairie Sun Greenhouses
Joffre, Alberta

Just before Christmas, 1983, Don McMullen of British Columbia Forest Products (BCFP) told us that we could grow 250 000 white spruce tree seedlings for their Berlund FMA, and that he wanted the trees seeded by mid-February in Styroblock 5s. This was a bit of a shock, because we had been talking to Brian Zak about growing 30 000; however, Tim Ellis, Al Fedkenheuer, and I were confident that it could be done. With Jim Kinghorn assisting and providing advice we were sure things would go smoothly.

By February 16, 1984, there were 300 000 cavities filled and seeded to white spruce. Our final soil mix was four parts peat moss, three parts vermiculite, and three parts perlite. To this we added Asmocote and trace elements. All mixing was done by hand. With some difficulty, three hand shuttle seeders were constructed and used for seeding. They worked fairly well and gave us three or four seeds per cavity.

Benches were quickly improvised using two-by-fours and concrete blocks. These proved adequate, although settling of the ground gave quite a bit of unevenness. Lights were installed to provide 40 foot-candles per square foot. An overhead watering system was placed in the growing area but was not used. Crop misting and watering was done by hand.

Germination was quite slow with 20°C days and 17°C nights. These are the temperatures we were using to grow the tomato crop in the rest of the greenhouse. Seeds were still germinating in early April. This slow germination may have been partly caused by a low-vigor seed lot and partly by too cool a temperature. As soon as germination appeared fairly complete, a feed of 10–52–17 was given. After that, the greenhouse feed for the seedlings was identical to that of the tomato crop.

Thinning and transplanting took place in early April. The crop was very uneven, and we attempted to fill in the empty cavities, with partial success. The seedlings showing root branching did not survive the transplanting process; however, as we had a survival rate of about 60%, I feel that transplanting at the thinning stage is profitable.

Once the thinning was accomplished the seedlings began to grow vigorously, and they went from germinant stage to 2 inches very quickly. At this stage the N:K ratio was 18:25. By mid-June, the first flush of growth had ended, and the plants were a dusty green color. Root growth was not heavy but was all a good white color. By the end of June the plants were flushing again after a heavy application of water. The largest plants were placed outside at this time for hardening. The smaller plants remained in the greenhouse to give them a chance to put on more growth under "ideal" conditions. The second night the seedlings were outside, the temperature dropped to 2°C, and the trees turned purple.

The seedlings remaining in the greenhouse did not get sufficient water to give significant growth. In mid-July the company (BCFP) said they wanted the seedlings August 7, so the remainder were placed outside on pallets. About one-third of the seedlings were under 7.5 cm in height.

During the time the seedlings were outside, they seemed to put on more growth than when they were in the greenhouse, even though conditions were somewhat harsh. Root growth and root collar diameter increased, and all shoot growth continued to flush.

It was a shock to discover the time required to package the seedlings for shipping. Pulling the trees from the Styroblocks was a major job. Although the blocks were off the ground on pallets, the roots did not air prune. Instead, they grew through the bottom of the blocks and did not fill in at the top of the plug. Air pruning at the bottom would have encouraged better rooting at the top, and the plug would have held together when pulled. We probably destroyed over 40 000 trees in the pulling process.

The total number of seedlings shipped was 237 000. Of these, about one-third did not meet either height (15 cm) or root collar diameter (3 mm) requirements. All seedlings shipped met the requirement that the plug must hold together.

Comments from the crew planting the trees were very favorable. Randy Hart of BCFP said that the plugs were among the best the planters had handled in 1984. A member of the planting crew told Tim Ellis and myself that an increase in height and less bottom root growth would be of great benefit. The planters also said that a stronger shipping box and a more adhesive wrap for the bundles would be better. We used a shrink-wrap to hold most of the bundles of 25 trees together.

For 1985 our approach will be a little different. With more time to prepare, the blocks will be filled ahead of time and stockpiled. A January seeding is anticipated, and germination temperatures will be higher than in 1984. I need 26 weeks to produce a crop meeting specifications. The most important factor, though, is to provide a system for even and adequate watering; even a poor system is sometimes better than none at all. With the volume of seedlings we grew it was difficult to provide enough water by hand.

At the suggestion of Jim Kinghorn and with the encouragement of BCFP and Beaver Plastic we are also trying a different growing regime. Sowing in June in small cavities and partially overwintering the seedlings should allow a spring transplant to a larger cavity and should produce a marketable tree by June the following year. We made a July sowing, and results so far are not encouraging. The seeds were placed in water on a Friday night, and by Monday they were already sprouting. Sowing was time-consuming, but germination was fast and good. High greenhouse temperatures almost wiped out the crop in a minimum of growing media. The greater the soil volume, the greater the survival rate. These seedlings will be hardened outside and brought back into the greenhouse in February. At this time they will be transplanted into Styroblock 5s and grown until June.

In conclusion, the tree seedling crop will continue to be part of our growing program at Joffre, and by August 1985 we expect to be planting top quality white spruce in the field.

FOREST NURSERY PRACTICE IN BRITISH COLUMBIA

Ralph F. Huber
British Columbia Ministry of Forests
Victoria, British Columbia

INTRODUCTION

In 1985, 160 million seedlings will be sown for British Columbia nurseries. Of these, 100 million will be produced in Forest Service nurseries.

Today, white spruce accounts for approximately 75% of the seedlings sown. Lodgepole pine, Douglas-fir (coastal and interior), cedar, and hemlock are other species sown. The purpose of this paper is to present various practices employed by B.C. Forest Service nurseries, with particular emphasis on central-interior nurseries.

THE NURSERIES

In 1985 there will be 36 nurseries growing seedlings for reforestation in B.C. Eleven of the 36 nurseries are Forest Service, eight are licensee, and the remainder are commercial. Of the 36 nurseries, 12 grow bare-root, and the remainder grow containers only. Of the 12 growing bare-root, four grow bare-root seedlings only, and the other eight grow both bare-root and container seedlings.

The production capacity of the bare-root nurseries varies from 150 000 to 30 million. In the container facilities, production capacity varies from 150 000 to a high of over 20 million. Production capacity of container facilities varies with the container size used.

SEEDLINGS PRODUCED

Seedlings sown in 1985 will total about 160 million (Table 1), with approximately 75% being spruce. Spruce is by far the most abundant species produced in B.C., followed by pine and fir. All seedlings produced are coniferous species.

In 1974, B.C. seeded 80 million seedlings, of which 62 million were bare-root and 18 million were container. In 1985, B.C. will sow 160 million seedlings, of which 50 million will be bare-root and 110 million will be container. During the past few years bare-root production has decreased and container production has increased.

Table 1. Seedlings sown by year since 1974

Year	Millions of seedlings		
	Bare-root	Container	Total
1974	61.9	17.8	79.7
1975	62.9	17.9	80.8
1976	60.2	20.0	80.2
1977	51.3	27.6	78.9
1978	68.3	28.4	96.7
1979	67.3	31.7	99.0
1980	82.7	43.0	125.7
1981	75.9	67.3	143.2
1982	69.9	81.0	150.9
1983	70.3	81.0	151.3
1984	57.9	98.1	156.0
1985	50.0	110.0	160.0

BARE-ROOT PRODUCTION

The Forest Service has seven nurseries that produce bare-root seedlings. Practice is identical at these nurseries except for the size of machinery used for particular cultivation practices. Cultural practices will vary from nursery to nursery because of soil types, climatic conditions, and water analysis.

So that prairie nurseries may compare their nursery practice to B.C. Forest Service practice, I will outline a complete rotation of 2–0 stock at our Red Rock Nursery, which is located 15 miles south of Prince George. I believe that conditions at this nursery are similar to prairie conditions. In our cropping system we work on a 3-year rotation, comprising 1 year of summer fallow and 2 years in a crop.

Fallow Period

During the year of summer fallow the land is kept cultivated to allow for solar pasteurization. Various tillage implements may be used to accomplish this. During the summer fallow period, deep ripping may take

place to loosen subsoil if tests show the need. Towards the end of the fallow period, soil samples are taken and analyzed for nutrient levels, pH, organic matter, pythium, and fusarium counts. The results of these analyses will affect treatments, such as fertilizer schedules or addition of organic matter. If the organic matter of the soil has to be increased, peat moss is added and worked into the soil in the fall. We aim for an organic level of ±4%.

Field Preparation

1. Agriculture limestone—600 kg/ha broadcast and worked in as soon as possible in the spring.
2. 0-45-0—broadcast and worked into soil prior to seeding.
3. 0-0-22—broadcast and worked into soil prior to seeding; level aimed at is 30 milliequivalents per 100 g of dry soil.
4. 11-55-0—inject when seeding. Desirable level of P is 275 ppm.

Seeding

Seeding takes place as early in the spring as possible. All seed is stratified prior to sowing. Prior to 1984, all bare-root seeding was done with either a Wind River or Oyard seeder. Unfortunately, these machines do not evenly distribute the seed, resulting in clumps of seedlings in the row and poor growth of some of the seedlings. The Oyard did a better job of seed distribution than the Wind River seeder but was still lacking in precision distribution. In 1984, all Douglas-fir and lodgepole pine were precision-sown. A limited amount of white spruce was sown on a trial basis. If we lower the density of white spruce we find more frost heaving.

All seedbeds in our nurseries are raised 5-6 inches. The beds are 48 inches wide and 68 inches center to center. Each bed contains seven rows, 6 inches apart; this is the standard in B.C. Forest Service nurseries.

We use two types of precision seeders.

1. Summit Precision Seeder

Manufactured by Summit Engineering of Rotorura, New Zealand, the Summit seeder originally was a unit designed to form beds, pack seed, and cover seed in one operation. We have never used the bed-shaping capability of the machine. In the future this seeder will be available in three models: seeder with a three-point hitch only, seeder with fertilizer injector, and seeder with bed-forming capability.

The vacuum sowing head on the Summit is one solid drum with seven rows of orifices, one corresponding to each row of nursery bed. Originally, the sowing drum was designed to handle large seeds for species such as Douglas-fir or ponderosa pine. Summit has since developed a drum that will handle both small seeds for species such as spruce or lodgepole pine, and large seeds.

With the Summit seeder, spacing within the row is dictated by two sprockets. Sprockets with a different number of teeth (14 to 69) are used to give a spacing of 1.0-13.0 cm. Table 2 gives an example of the spacing the seeder is capable of.

When seeding with the Summit, speed of travel is very important. The recommended travel speed is 60 feet (18 m) per minute. Accuracy of the machine decreases as travel speed increases.

Table 2. Spacing capability of the Summit Precision Seeder showing the number of seeds laid down in seven rows per bed metre

Interseed spacing (cm)	Seeds per bed metre
1.00	700
1.26	555
1.53	457
1.75	400
2.00	350
2.27	308
2.47	283
2.75	254
3.07	228
3.30	212
3.46	202
3.79	184
4.01	174
4.21	166
4.45	157
4.71	149
4.95	141
5.20	135

2. Miniair Precision Seeder

Manufactured by H. Fahse and Co. of Duren, West Germany, the Miniair is used extensively for agricultural purposes in Europe. We used this machine for sowing lodgepole pine and a limited amount of white spruce on an experimental basis.

In contrast to the Summit, which has one vacuum drum for sowing seven rows, the Miniair has seven individual sowing heads. Each sowing head has a vacuum disc with orifices for picking up seed. The Miniair will work only with smaller-seed species.

With the Miniair seeder, spacing within the row is dictated by four gears. By interchanging the gears the machine can achieve spacing from 0.06 to 6.0 cm. Table 3 gives an example of the spacing the seeder is capable of. Distances between seeds greater than those in Table 3 can be achieved by using a smaller drive sprocket.

As with the Summit seeder, speed of travel is important. The factory recommends that ground speed should be such that the seed can be visible on the rotating seed pickup discs. Our experience is that this is approximately 65 feet (20 m) per minute. Accuracy of the machine decreases as speed of travel increases.

Table 3. Spacing capability of the Miniair Precison Seeder showing the number of seeds laid down in seven rows per bed metre

Interseed spacing (cm)	Seeds per bed metre
0.6	1 167
0.8	875
0.9	778
1.1	636
1.3	538
1.5	467
1.8	389
1.9	368
2.3	304
2.7	289
2.9	241
3.0	233
3.5	200
3.9	179
4.6	152
6.0	117

Sowing

Sowing rules vary from nursery to nursery. Historical data is used to establish sowing rules. Table 4 gives the sowing rules for the Red Rock Nursery.

Table 4. Projected recovery of plantable seedlings per bed metre by viable seed sown

Species	Viable seed per metre sown	Projected recovery	Sowing factor	Recovery factor (%)
Lodgepole pine	300	200	1.50	67
White spruce	590	215	2.74	36

In precision sowing, around 300 viable seeds per bed metre is desirable, regardless of germination percentage. As seed viability decreases, an adjustment must be made in spacing to accommodate the extra seed. Table 5 gives the spacing we use for sowing lodgepole pine.

For seed cover we do not use native soil. When sowing, seed is laid into a shallow trench, and the entire seedbed is covered with coarse sand. After sanding, the seedbed is not disturbed for the 1st year.

Table 5. Sowing rules for lodgepole pine

Seed viability (%)	Interseed distance (cm)	Seeds per metre sown	Viable seed per metre sown
91-100	2.23	314	286-314
81-90	1.99	351	284-316
71-80	1.76	397	282-318
61-70	1.53	458	279-321
51-60	1.30	540	275-324
41-50	1.06	659	270-329
40	*	Variable	360

1-0 Fertilizing

The fertilizer schedule for 1-0 white spruce and lodgepole pine is as follows:

21-0-1—60 kg/ha mid-June after secondary needle formation and repeat every 7-8 days until end of 1st week in August.

11-55-0—100 kg/ha end of June with 21-0-0 application.

0-0-50—85 kg/ha end of June with 21-0-0 application.

0-0-50—85 kg/ha end of 1st week in August.

11-55-0—170 kg/ha late August, early September

Sawdust—Seedbeds mulched with 1 inch early October for frost protection.

1-0 Irrigation

- Following seeding and prior to emergence, irrigate every day. Irrigate prior to noon. This allows soil to warm for germination.
- During emergence and the initial growing period, keep moisture levels at optimum.
- During emergence and early growth, use irrigation for cooling. Do not allow temperature to exceed 27°C.
- As seedlings develop needles, which result in shade, gradually increase temperature to 28°C and then to 30°C.
- Irrigate as required for optimum growth.
- As long as growth is wanted, keep temperature below 30-31°C.
- Protect from frost, if necessary.

Weed Control

Prometryne: 0.5 kg/ha a.i. in 1100 L of water as a broadcast spray. Not used again until next 1-0 crop to avoid Triazine buildup.

A.W.K.: 450 L/ha as a preemergent spray.
Gesagard: 0.56 kg/ha a.i.
Hand weeding: as required
Basket weeding

2-0 Fertilizing

The fertilizer schedule for 2-0 white spruce and lodgepole pine is as follows:

Fertilizer	kg/ha	Date
11-55-0	220	Early April
21-0-0	90	Just before bud swell
0-0-50	110	Early April
11-55-0	110	Late April or early May
34-0-0	60	Mid-May
21-0-0	90	Late May, early June
21-0-0	56	Mid-June
21-0-0	110	Late June
0-0-50	85	Late June
34-0-0	90	Early July
11-55-0	110	Mid-July
21-01-0	56	Mid-July with 11-55-0
21-0-0	90	Late July
34-0-0	60	Early August
0-0-50	100	Early August
11-55-0	75	Mid- to late August, after bud set
21-0-0	90	Mid-September, after consultation

2-0 White Spruce Root Culture

Date	Operation
Early April	Deep wrench with level blade
May 16	Undercut 12.5 cm
June 11	Lateral prune
June 13	Wrench 20 cm after top growth achieved
June 23	Wrench
July 2	Wrench
July 23	Wrench
July 30	Wrench
August 7	Wrench
August 20	Wrench
August 27	Lateral prune
Late October	Lift to storage

2-0 Lodgepole Pine Root Culture

Date	Operation
Early April	Deep wrench with level blade
Mid-April	Undercut 10-12.5 cm
May 31	Lateral prune
Mid-June	Wrench after top growth achieved
Mid-July	Undercut 20 cm
Early August	Wrench
Late August	Lateral prune
(More wrenching may be required to hold crop back.)	
Late October	Lift to storage

2-0 Irrigation

- When it becomes apparent stock will attain target, judicious irrigation should be practiced.
- Whenever possible, irrigation, fertilizer applications, and wrenching should be combined.
- The same heat protection that is used on 1-0 may be used on 2-0 if ambient crop temperature is above 31-32°C.
- During the hardening-off phase in August and September, adequate levels of moisture must be maintained.

Lifting

Up until 1983, all lifting was done using either a Grayco or Fobro lifter. Seedlings, in the case of the Grayco, were deposited into tote-boxes at the rear of the machine and were then lifted onto a trailer traveling alongside. With the Fobro lifter, we had from 12 to 16 people picking up seedlings from the seedbed, placing them into tote-boxes, and putting them onto a trailer. We saved manpower in the lifting process by installing a side delivery system on the rear of the Grayco to transport seedlings up into bins on the trailer. Also, we used bins instead of tote-boxes.

Grayco lifter

Manufactured by Evergreen Tree Seedling Harvesters, Heidelberg, Ontario, our Grayco lifters originally were equipped with personnel carriers. The personnel carriers saw limited use in our operations. When the idea of a side delivery and bin system came up, the first place we looked for parts for fabrication was the personnel carriers. All parts for the side deliveries, such as chains and hydraulics, were taken from the personnel carrier. Side delivery eliminates seven people in the field, thus saving a considerable amount of money.

Fobro lifter

This machine is manufactured by Baertschi & Co. Ltd. of Hueswil, Switzerland. For the past few years we have been using Fobro lifters in a number of our nurseries. Up until 1983, we had from 12 to 16 people following the Fobro picking up seedlings from the seedbed, placing them in tote-boxes, and stacking them onto a trailer. In 1983, we purchased our first Fobro combine to pick up seedlings from the seedbed and transport them up and over to a trailer with field bins. Since our first model was purchased, we have made numerous modifications to the combine. The major modifications were the use of potato digger chains instead of belts, which eliminated a lot of soil in the bins, and a lift on the side delivery system so tractors can pass under when changing trailers.

From the field, the loaded bin trailers are taken to the cold storage-sorting complex. Bins are stacked in a cold storage compartment prior to going into the sorting shed for grading and packaging. The first bins into the cold storage are the first out.

Sorting Room

The sorting room has two tables, which usually accommodate 20 workers on each side, for a total of 80 sorters. At the end of each table workers bundle, root-prune, and pack seedlings. The bundled seedlings are packed into a waxed carton lined with a Kraft poly-coated bag. When the bag is full it is rolled shut, and the carton is closed and stapled. The carton is then marked with the seedlot number, date lifted, date packed, stock type, and nursery of origin. The carton is then ready for cold storage.

All stock is sorted to specifications. An example of the specifications for Red Rock Nursery could be as follows:

Lodgepole pine

Height:	Target 15.0 cm; minimum 12.5 cm
Caliper:	Target 3.0 mm; minimum 3.0 mm
Roots:	Good judgment

White spruce

Height:	Target 18.0 cm; minimum 13.5 cm, maximum 30.0 cm
Caliper:	Target 4.0 mm; minimum 3.0 mm
Roots:	Good judgment

Stock specifications can vary from seedlot to seedlot, depending on the original order.

Cold Storage

All cartons of stock are set on pallets, which are set into racks in the cold storage units. All cartons have one side exposed to the ambient temperature. Most stock is freeze-stored. Stock is held in cold storage until shipment to the planting site.

Note: At this point, I remind you that what works for one nursery may not work at another location.

CONTAINER PRODUCTION

The Forest Service has 10 nurseries that produce container seedlings. Practice is basically identical at all nurseries. Some changes in cultural practice will occur from nursery to nursery because of climatic conditions and water analysis. As in bare-root production, I will use container production at Red Rock as a guideline.

Containers

White spruce	Styroblock 313A 198 cavities per block 87 cavities per sq. ft. cavity volume 4 in.^{3}
Lodgepole pine	Styroblock 211 240 cavities per block 103 cavities per sq. ft. cavity volume 2.5 in.^{3}

Growing Media

White spruce	3:1 peat-vermiculite mix 6.5 kg/m^3 Osmocote 18-6-12

Both mixes have Dolomite line 10 mesh or finer added at a rate of 2.0 kg/m^3. Lime application depends on water quality.

Seeding

Seeding is done on predetermined dates. This allows seed to be withdrawn from storage and stratification. All seeding is done with a Vancouver Bio-machine seeder. Table 6 gives the sowing rules for container seedlings.

Cultural Schedule

For white spruce, the greenhouse cultural schedule is as follows:

March 25	Sow Mist frequently Water as required Greenhouse temp: day 21°C, night minimum 13°C 19-hour intermittent light
April 22	Stop misting Fertilize 10-52-17 at 750 g/(1000 L)
May 7	Fertilize 20-20-20 at 625 g/(1000 L) Ferrous suplhate at 150 g/(1000 L) every 3 weeks
June 21	Expose crop to full light (direct sun) Fertilize as above if salinities less than 1000 micromhos, otherwise water only
August 21	Return crop to greenhouse Fertilize 10-52-17 at 750 g/(1000 L) Greenhouse temp: day 13°C, night minimum 8°C
September 14	Greenhouse temp: minimum 8°C Fertilize 10-52-17 at 750 g/(1000 L) Ferrrous sulphate at 150 g/(1000 L) monthly
October 1	Greenhouse temp: minimum 2°C Fertilize: as above
November 1	Lift if stock frost hardy

Table 6. Sowing rules[1]

Rule[2]	Germination (%)	Sowing factor (no. of seeds per cavity)	Correction factor (total no. of cavities to sow); all species
2 a	100-96	2	1.15
b	93-95	2	1.20
c	90-92	2	1.25
d	86-89	2	1.30
3 a	81-85	3	1.20
b	76-80	3	1.25
c	71-75	3	1.30
d	66-70	3	1.35
4 a	61-65	4	1.40
b	56-61	4	1.45
c	51-55	4	1.50
d	46-50	4	1.55

[1] Seedlots of 15 000 seedlings or less are to be hand sown. The allowance for extra seed for these seedlots is to be 20% of the number of cavities sown.

[2] Additional seed to be added to each seedlot for seeder hopper and handling loss is 10 g plus 20% of the number of cavities to be sown for requests of up to 50 000 trees, and 10% for requests in excess of 50 000 trees.

For lodgepole pine, the shade house cultural schedule is as follows:

April 25	Sow Mist frequently Water as required Temp: day 21°C, night minimum 13°C
May 22	Stop misting Fertilize as required 20-20-20 at 625 g/(1000 L) ferrous sulphate at 150 g/(1000 L) every 2 weeks
July 1	Expose crop to full light Fertilize as above
August 21	Return crop to greenhouse Fertilize 10-52-17 at 750 g/(1000 L) Temp: day minimum 13°C, night minimum 8°C
September 14	Fertilize 10-52-17 at 750 g/(1000 L) and ferrous sulphate at 150 g/(1000 L) monthly Temp: minimum 8°C
October 1	Fertilize as above Temp: minimum 2°C
November 1	Lift if stock frost-hardy

Lifting

In B.C., all container stock is lifted, graded, bundled, and packed into similar containers as for the bare-root. A predetermined number of shippable seedlings are put into a bundle. The bundle is then wrapped with Vita-film (similar to Saran Wrap) and placed into the bag in the carton. Bundled seedlings are either stood up in the carton or laid down, depending on seedling size.

An example of stock specifications is as follows:

White spruce

Height:	Target 20.0 cm; minimum 15.0 cm
Caliper:	Target 2.7 mm; minimum 2.5 mm
Top dry wt:	Target 1.2 g; minimum 0.9 g
Root dry wt:	Target 0.7 g; minimum 0.5 g

Lodgepole pine

Height:	Target 12.5 cm; minimum 7.0 cm
Caliper:	Target 3.0 mm; minimum 2.2 mm
Top dry wt:	Target 0.8 g; minimum 0.6 g
Root dry wt:	Target 0.5 g; minimum 0.35 g, maximum 0.65 g

Cold Storage

Cartons of container stock are treated the same as bare-root stock.

This gives an overview of bare-root and container growing in British Columbia Forestry Service nurseries. We are continually changing some of our practices; therefore, what has been presented here may not be our practice a few years from now.

OPERATIONAL TRIALS OF A SHROUDED HERBICIDE SPRAYER FOR WEED CONTROL IN FOREST NURSERY SEEDBEDS

Jim Atkinson
Nursery Superintendent
Pineland Provincial Forest Nursery
Department of Natural Resources
Hadashville, Manitoba

Weed control at the Pineland Provincial Forest Nursery is a labor-intensive undertaking. Despite the use of a soil fumigant and a mechanical bed-weeder, hand weeding remains a major method of weed control. The hand weeding cost for 1 year on an inventory of 1–0, 2–0, and 3–0 crop rotations is approximately $75,000, or one-half cent per seedling. Bare-root stock production is expected to nearly double in the next few years, with a corresponding increase in the amount of weeding required.

Consequently, an innovative herbicide sprayer has been developed at the Pineland nursery for chemical control of weeds in the bare-root beds. This sprayer, which was developed by Pineland nursery staff, applies herbicide only to the area between the rows of seedlings within the beds themselves. The spray itself is shrouded to confine its effect to the target area and to prevent the herbicide from coming into contact with the seedlings.

The sprayer unit consists of a 300 L plastic tank, a PTO-powered pump, a pressure-regulating valve, a pressure gauge, and eight shrouds arranged on a boom to correspond to the distance between seedling rows. The boom supporting the shrouded nozzle spray-tips is carried between the front and rear wheels of the tractor.

In July 1984, operational trials of the sprayer unit were conducted on bare-root seedbeds containing red pine 2–0 and white spruce 1–0 and 3–0 stock, using two herbicides: Weedkiller 350 and Roundup. A variety of herbicides and application rates can be used, as the spray volume can be adjusted by changing the spray pressure and nozzle tip size. Herbicide cost is kept to a minimum because spraying is done only between rows. With the row spacing used at the Pineland nursery, a pass width of only 1.12 m (44 inches) is all that is required.

As is often the case with many bare-root field operations, the quality of the work performed is largely dependent upon operator skill. To simplify the task, the sprayer is mounted so that the operator has a clear view of the progression of the unit as it travels down the beds.

In the trials, Glyphosate (Roundup) was used on portions of four fields. A 1% solution of Roundup in water was used at several application rates to determine the optimum coverage. Because of Glyphosate's ability to move through the plant from the point of foliage contact to and into the root system, we were particularly interested in applying it with the sprayer. We hoped that weed species such as portulaca, with its abundant prostrate branches, would be effectively controlled by applying Glyphosate to whatever branches were between the seedling rows, so that the herbicide would be translocated to the root, thereby killing the entire plant whether or not it was completely sprayed. The trials proved that we could achieve very good control of quack grass, thistle, dandelion, plantain, ragweed, and June grass.

Portulaca and field horsetail, two major problem weeds at the Pineland Provincial Forest Nursery, proved to be more difficult to control. One of the four test plots established to assess the effectiveness of Roundup contained considerable amounts of portulaca. This plot was sprayed July 12, 17, and 23. It is noteworthy that 30 mm of rain fell within 6 hours of the first spray application of July 12. The first effects of the herbicide were noted July 20, and by August 1 the portulaca was 75% yellow and noticeably withered. Even with the three applications, however, the portulaca did not die out altogether, although it was certainly stressed to the degree that it would not spread. Unfortunately, subsequent sprayings of test plots containing field horsetail were not conducted, so Roundup's effectiveness in controlling it remains inconclusive; however, where field horsetail occurred alongside other weeds it exhibited comparable resistance to Roundup.

Weedkiller 350 was used on four test plots and yielded results within 24 hours. June grass, dandelion, quack grass, and field horsetail within the spray area were killed within a week. Where the weed was rooted in the seed bed, only the foliage in the spray area became chlorotic and died, leaving the unaffected portion of the plant to regenerate. In fact, some weed species, such as

field horsetail, appeared to become even more prolific after spraying.

One unexpected effect of Weedkiller 350 was its control of algal growth in the beds. Algae growing on the soil in the spray area was killed, creating a very noticeable demarcation between the spray and nonspray area.

In conclusion, we were quite pleased with the results of the field trials of this sprayer unit. We were able to control weeds while shielding bare-root seedlings from any detrimental effects of the herbicides, although the occasional seedling protruded into the spray area. In general, no ill effects have been observed in the beds sprayed. A certain degree of caution must still be exercised, and before this sprayer becomes an operational tool, a few more trials will be conducted in the summer of 1985. These trials will primarily be to determine the sprayer's effectiveness on field horsetail, the ramifications of repeated spraying, and the possibility of physical damage to larger stock.

In the past, the use of chemical weed control has not been the practice at the Pineland Provincal Forest Nursery, due to a number of considerations; however, with the advent of this sprayer that will eliminate any side effects, and with the expanded scale of operations, we feel that we must seriously pursue more cost-efficient methods of weed control.

PINE RIDGE EXPERIENCE IN GREENHOUSE IRRIGATION

Peter N. Au
Pine Ridge Forest Nursery
Smoky Lake, Alberta

INTRODUCTION

Because this talk was a slide presentation illustrating the irrigation experience at Pine Ridge greenhouses, the following is an outline of the presentation, including a brief description of the container program.

CONTAINER PROGRAM

Using a two-crop system, Pine Ridge can produce 20 million container seedlings annually in its 3.5-acre greenhouse complex. Each of the 20 greenhouses (42 × 180 ft.) is capable of growing 500 000 seedlings on a one-crop system. All environmental conditions, such as temperature, humidity, irrigation, supplemental lighting, fertilization, and the addition of carbon dioxide to the atmosphere, are set and monitored.

The greenhouse complex consists of a headerhouse corridor and 20 greenhouses. Ten greenhouses are attached to each side of the corridor. Water is pumped to the north end of the headerhouse corridor from the in-site pump house, which is located next to the 12-million gallon reservoir. This pump house supplies water to the bare-root fields and shade frames, and to residential areas, as well.

ORIGINAL GREENHOUSE IRRIGATION SYSTEM

From the north end of the headerhouse corridor, water is delivered to each greenhouse via a 2½-inch PVC overhead line that runs along each side of the corridor. The PVC pipe connects to a 2-inch metal pipe that extends to the greenhouse above the doorframe. At the end of the greenhouse, close to the headerhouse, the 2-inch metal line branches out to four overhead irrigation lines of 1-inch aluminum pipe that are 170 feet long. These four lines are spaced 10 feet apart, and are 6 feet from the greenhouse wall.

DGT misting nozzles (2.0 gal./min.) are used and are spaced 8 feet apart to form irrigation grids of 8 × 10 feet.

TROUBLESHOOTING

Following the start of the greenhouse operation in 1978, and in subsequent years, there were irrigation patterns of uneven growth during the seedlings height growth stage inside the greenhouse. Troubleshooting was started to identify the problem.

First, it was identified that the line pressure of the four 170-foot-long aluminum overhead irrigation lines were slowly dropping away from the supply end. Due to the length of the line and the location of the branch line, an even pressure could not be maintained.

Second, it was identified that the line pressure of the 2½-inch PVC line along the corridor fluctuated when the pump house had to supply water simultaneously to bare-root fields and shade frames or other areas.

IMPLEMENTATION OF CHANGES

Since 1982 the following changes have been made:

1. The 2-inch metal line inside the greenhouses was extended to the middle of the greenhouse (about 80 ft. from the end) and was connected to the four overhead irrigation lines. With this modification, the water travels an equal distance to reach both ends, thus maintaining an even line pressure.

2. A booster pump of 10 horsepower was installed at the north end of the headerhouse corridor, where the 2½-inch PVC line begins. This pump can maintain constant pressure of the main water supply line at times when the pump house has to supply water to other areas.

RESULTS

The two modifications were completed before the 1984 growing season. The inspection of the 1984 crops confirmed the elimination of irrigation patterns of uneven growth.

DETERMINING IRRIGATION REQUIREMENTS OF CONIFER SEEDLINGS

J. Cruickshank
PFRA Tree Nursery
Indian Head, Saskatchewan

INTRODUCTION

The efficiency and effectiveness of irrigation depends to a large degree upon the frequency and duration of applications. Although tensiometers, gravimetric soil moisture determinations, and the soil moisture budget method are commonly used for irrigation scheduling at tree nurseries, experience at the Indian Head Tree Nursery suggested that these methods did not satisfactorily indicate the length of irrigation time required. Other procedures were therefore employed to establish the length of time required for irrigating at various stages of the soil drying cycle.

The objective of this experiment was to determine the optimum length of time of irrigation and to evaluate methods of determining the frequency of irrigation required for 2-1 Scots pine seedlings on Indian Head clay loam soil.

MATERIAL AND METHODS

The depth at which soil moisture should be monitored for irrigation scheduling was determined. We obtained gravimetric soil moisture data and moisture characteristics curves by measuring soil matric suction. Data were collected for three soil layers (0–5, 5–10, and 10–15 cm). A critical depth for monitoring soil moisture levels was then determined, based on the severity of dessication of various soil layers and seedling tolerance to the moisture regimes of the respective soil layers. Soil with a matric suction of 0.3 bars was considered to be at field capacity, a near-optimum moisture regime for tree growth. Values that exceeded 1.0 bar indicated that moisture levels were suboptimal for plant growth. The permanent wilting point was considered to be approximately 15.0 bars. Once a depth was established for monitoring soil moisture, the soil was monitored continuously to determine when irrigation should be applied. The second procedure used to determine when to irrigate was the moisture budget method. This procedure involved measuring moisture gains through irrigation and precipitation, and losses through soil drainage and evapotranspiration. The resulting moisture level of the soil was then used to calculate the moisture deficit, which indicated when to irrigate. Subsurface drainage was observed by exposing soil profiles to a depth of greater than 30 cm. Evaporation pan data, adjusted with a correction factor, were used to estimate evapotranspiration. This correction factor is referred to as a "cropping factor," and for the purpose of irrigation scheduling is often assumed to be constant for a given soil type and tree cover. It is calculated by the formula:

$$\frac{\text{(mm water lost to evapotranspiration)}}{\text{(mm water lost from evaporation pan)}}$$

Evapotranspiration for a 3-day period was calculated using mean cropping factors and was then compared with actual evapotranspiration values measured directly with lysimeters.

Three procedures were used to estimate the quantity of water to be applied in an irrigation. In the first procedure, soil samples were randomly taken to determine porosity. The soil porosity values and the moisture characteristic data were then used to calculate the amount of irrigation required to raise the level of soil moisture to optimum levels for seedling growth. The second procedure compared soil drying cycles. The soil was allowed to dry for several weeks during the months of June and July following an irrigation. Soil samples were then taken at three depths: 0–5, 5–10, and 10–15 cm. Soil suction levels were determined before irrigating and at intervals throughout the drying cycle. Using a line-source sprinkler system, field plots were irrigated for various lengths of time, ranging from one-half hour to 8 hours. The drying cycles of the various plots were then compared. The third procedure used to estimate the quantity of water required for an irrigation was the moisture budget method, previously described. The moisture level of the soil was used to calculate the moisture deficit, which indicated the quantity of water required for an irrigation.

RESULTS AND DISCUSSION

Mean soil suction values of sampled sites ranged from greater than 15.0 bars in the surface layer, (0–5 cm), to 2.4 bars in the middle layer (0–5 cm) and 0.6 bars in the deepest layer (10–15 cm). The low suction values for the deepest layer indicated that, under drought

conditions without irrigation, soil moisture was generally adequate for seedling growth. It was apparent that even under the driest conditions there was rarely a large deviation from optimal moisture conditions at this depth for plant growth. Data suggested that at the 5–10 cm depth, moisture was adequate for seedling survival but was inadequate for optimal seedling growth. Moisture in the top 5 cm of the soil profile appeared to be insufficient for seedling survival; therefore, moisture content in the lower portion of the root zone (5–15 cm) was adequate. As a result, moisture levels in the surface 5 cm of the soil profile should be the primary concern when monitoring soil moisture for irrigation scheduling.

Although the surface layer of soil became extremely dry in the late stage of the drying cycle following a 4-hour irrigation, it was noted that this layer retained low matric suction values for the longest period of time. It was therefore apparent that suction values approaching 1.0 bar in the surface soil layer would be the best indicator of the onset of moisture stress.

For the moisture budget procedure, subsurface drainage following irrigation was found to be negligible. Data in Table 1 indicate the range of evapotranspiration values that could be expected, and the actual values obtained from lysimeters.

Table 1. Comparison of evapotranspiration values determined directly by lysimeters and values determined with evaporation pan data and cropping factors (95% confidence)

Irrigation treatment (mm)	Evapotranspiration from lysimeter (mm)	Evapotranspiration from cropping factors (mm)
8.0	7.5	5.3–10.0
22.0	10.2	8.0–12.0

Based on cropping factors, the number of hours of irrigation required to replace the water lost through evapotranspiration could be expected to range from 1.3 to 2.5 hours for the first treatment and from 2.0 to 3.0 hours for the second treatment. Because of the high daily variability in cropping factors, the moisture budget approach did not appear to be superior in any way to the use of soil moisture characteristic curves.

Calculations of irrigation time requirements based on soil porosity and matric suction measurements gave a wide range of values. Depending on the soil sample, requirements ranged from 2 to 6 hours of irrigation. Because of the high soil variability, this method was considered to be unsatisfactory for determining the quantity of irrigation that should be applied.

The soil drying trends for various irrigation treatments are presented in Figure 1. Data are presented only for the 0–5 cm soil layer because this layer was considered to be the critical depth for monitoring soil moisture. Drying trends were observed up to 3 days after irrigation, but moisture variation was too great after the 3rd day of drying to discern any differences in drying trends. The effectiveness of irrigation in maintaining moisture in the 0–5 cm layer increased with the length of irrigation, up to 4 hours. Applications of more than 4 hours showed no additional benefit.

CONCLUSION

It was found that the most appropriate way to schedule irrigation at the Indian Head Tree Nursery was to irrigate for a period of approximately 4 hours (16 cm of water) whenever soil matric suction levels approached values of 0.7–1.0 bars at a depth of approximately 5 cm. Monitoring moisture levels at such a shallow depth would exclude the possibility of using tensiometers.

The moisture budget approach to scheduling irrigation was considered inappropriate for the Indian Head Tree Nursery. The difficulty in using this approach arose primarily from inaccuracies inherent in the method used to estimate evapotranspiration.

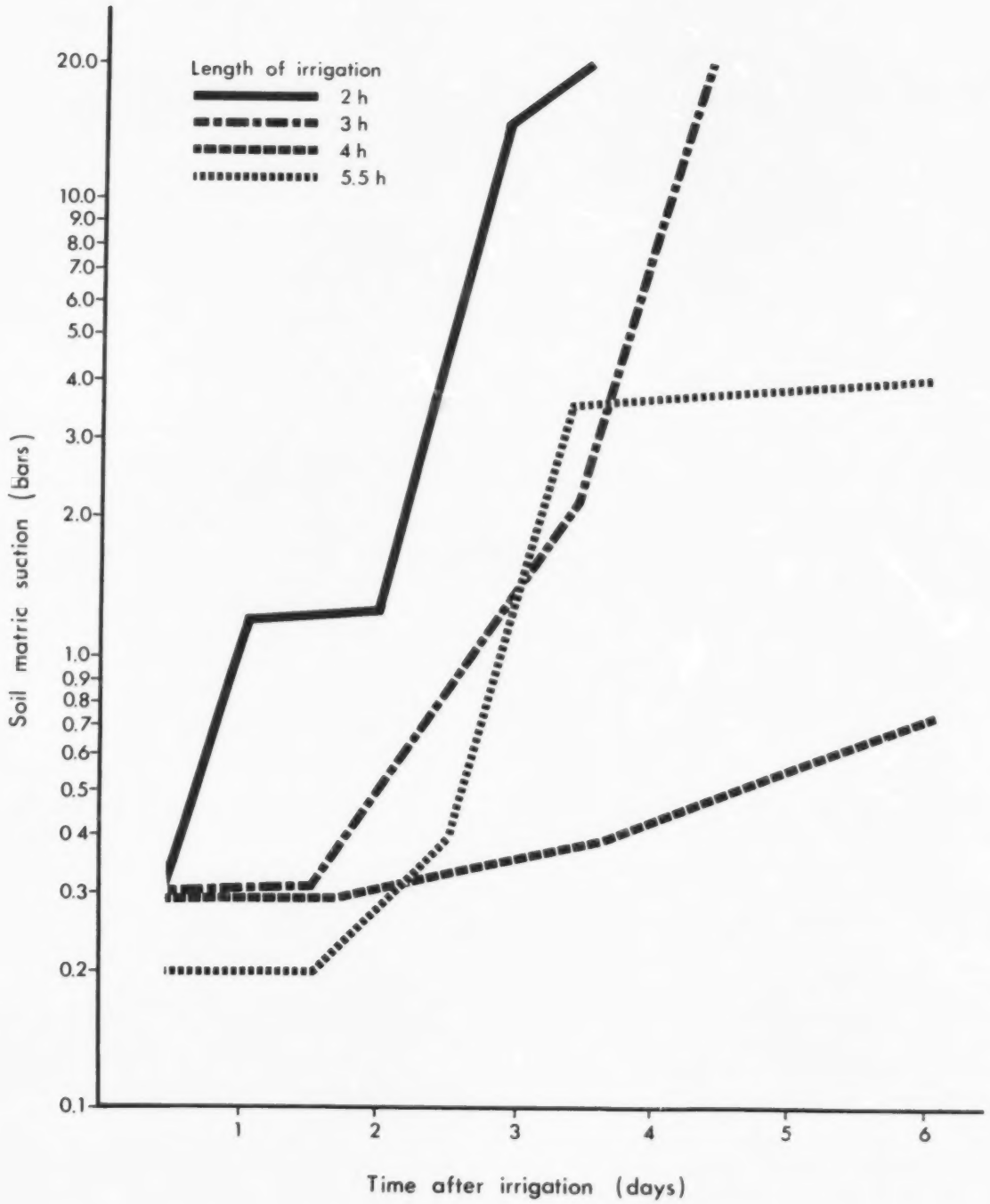

Figure 1. Effect of duration of irrigation on soil drying.

CONDITIONING CONTAINERIZED TREE SEEDLINGS FOR COLD TOLERANCE

I.K. Edwards
Research Scientist
Northern Forest Research Centre
Edmonton, Alberta

ABSTRACT

Containerized 16-week-old lodgepole pine and white spruce seedlings were conditioned with reduced photoperiod and day-night temperatures for varying periods of up to 6 weeks before undergoing a cold tolerance test at −5°C for 72 hours. Six weeks of conditioning with reduced photoperiod and chilling was insufficient to induce cold tolerance in lodgepole pine. White spruce showed the highest tolerance after 6 weeks of conditioning, but acceptable hardiness developed after 4 weeks.

INTRODUCTION

Conditioning of containerized conifer seedlings to develop cold tolerance is an essential phase of the production system, particularly in the prairie provinces. In order to withstand early frost in the fall, freeze-thaw cycles during winter, and late frosts in the spring, the seedlings must be sufficiently conditioned to develop tolerance to freezing conditions. Tinus (1974) has outlined the physiological prerequisites for development of cold tolerance in stock being grown in large containers for shelterbelt planting. The objective of this study was to determine the effect of conditioning time on the development of cold tolerance in containerized lodgepole pine and white spruce seedlings.

MATERIALS AND METHODS

Lodgepole pine and white spruce seedlings were grown for 16 weeks in peat in Spencer-Lemaire Ferdinand containers in the greenhouse under sodium-vapor lights. During the growing period (March-June), photoperiod was 18 h, day temperature was 24 ± 1°C, night temperature was 16 ± 1°C, and relative humidity was 60%. A fertilizer solution containing 125 ppm N, 60 ppm P, 159 ppm K, and micronutrients (Carlson 1983) was applied weekly, and the seedlings were watered as required.

For conditioning, supplementary light was turned off, and photoperiod was reduced to 8 h using black cloth for shading. The trays were flushed with water and were then allowed to dry for 10 days to nearly constant weight before being treated weekly with a fertilizer solution containing 44 ppm N, 101 ppm P, and 156 ppm K, and micronutrients as recommended (Carlson 1983). Day temperature was reduced to 15°C, but night temperature could not be reduced below 10°C because of the black cloth shading in the greenhouse.

After the seedlings were conditioned for 3, 4, 5, and 6 weeks they were transferred in trays to a cold room (−5°C) for 72 hours. They were returned to the greenhouse (22 ± 2°C) and observed for 4 weeks, during which time evidence of frost damage and mortality were noted.

RESULTS AND DISCUSSION

During the conditioning period of up to 6 weeks, lodgepole pine did not set bud and developed high mortality (95%) when subjected to sub-zero temperatures. Most of white spruce set bud during the conditioning phase: 28% after 3 weeks, 70% after 4 weeks, 42% after 5 weeks, and 95% after 6 weeks. Survival after the cold tolerance test was directly related to the percentage bud set during the conditioning period.

Lack of bud set in lodgepole pine was probably due to insufficiently low day and night temperatures during conditioning. Use of black cloth to shade the seedlings from extraneous light during summer invariably caused an increase in temperature. White spruce, however, was more sensitive to light intensity and photoperiod than lodgepole pine. It set bud adequately after 4 weeks of conditioning, although 6 weeks resulted in maximum survival. The decline in survival of spruce after 5 weeks of conditioning is anomalous.

CONCLUSION

Four weeks is presently the recommended conditioning period for either lodgepole pine or white spruce, but results indicate that the recommendation for spruce should be 6 weeks. Day and night temperatures during conditioning need to be 10°C and 2°C before a recommendation for lodgepole pine can be made. A subsequent experiment is planned in which the chilling phase (10°C days and 2°C nights) is conducted in a growth chamber.

REFERENCES

Carlson, L.W. 1983. Guidelines for rearing containerized conifer seedlings in the Prairie Provinces. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-214E.

Tinus, R.W. 1974. Large trees for the Rockies and plains. Pages 112–118 *in* R.W. Tinus, W.I. Stein, and W.E. Balmer, eds. Proceedings of the North American containerized forest tree seedling symposium. Great Plains Agric. Counc. Publ. 68.

EFFECTS OF LIGHT QUALITY AND PHOTOPERIOD ON TWELVE CONIFEROUS SPECIES

Ian J. Dymock and Sherry Wilson
Northern Forest Research Centre
Edmonton, Alberta

ABSTRACT

Seedlings of 12 coniferous species were exposed to four different treatments for a 7-month period: 18 hours under fluorescent light, 24 hours under fluorescent light, 18 hours under high-pressure sodium lamps, and 24 hours under high-pressure sodium lamps. Height growth, root collar diameter, and the number of branches were significantly higher under the high-pressure sodium lamps than under the fluorescent lamps for most of the species studied. Photoperiod within light treatments was not significantly different with respect to growth, suggesting that light quality and not photoperiod was important for morphological effects. Root growth appeared to be better developed under sodium lamps than under the fluorescent, but within light treatments the 18-hour photoperiod seemed to produce a better developed, fine root system.

INTRODUCTION

Tree seedlings are commonly grown artificially in nurseries and greenhouses for both research and production purposes. The ability to grow healthy, normal seedlings in a limited amount of time and with the least expense is desirable. Both light quality and photoperiod may produce morphogenetic effects, with some effects being more desirable than others.

Light quality refers to the composition of light and is especially important in the photosynthetically active region (PAR) between 400 nm and 700 nm. The spectral distribution of light is more important than overall light output for morphogenetic effects (Vince-Prue and Canham 1983).

Light quality has been shown to modify branching, amount of foliage, and stem extension in herbaceous species (Smith 1982). These differences in growth are primarily attributed to the red:far-red (R:FR) ratio, also known as the zeta ratio, which is the ratio of the quantum flux at 660 nm and 730 nm (Morgan and Smith 1976).

Pinus radiata has shown increased shoot elongation, internode length, and proportion of stem weight in R:FR ratio of 1.15 compared to 4.59 and 1.51 (Morgan et al. 1983). *Pinus contorta* seedlings grown under a 24-hour photoperiod have also been shown to grow considerably faster than normal nursery-grown controls (Wheeler 1979).

This study was concerned with defining accelerated normal growth for coniferous greenhouse crops. Light quality and photoperiod were used to determine the best combination for growth of 12 coniferous species.

MATERIALS AND METHODS

The following materials and methods were used in the experiment:

1. **Seed material:** Seed from 12 coniferous species was obtained as outlined in Table 1. Seeds had been kept in storage at approximately −10°C.

2. **Potting:** Spencer-Lemaire Super 45s (700 cm^3 volume) were filled with Sunshine brand peat moss. Lime ($CaCO_3$) was added at a rate of 350 g/170 L bale of peat, which effectively raised the pH to approximately 5.5. All containers were seeded March 7, 1983 and covered with #2 granite grit.

   The containers were placed in the greenhouse with ambient air temperatures of 25°C in the day and 18°C at night. Thinning occurred 4 weeks after seeding (to one seedling per container), and light treatments began April 25, 1983.

3. **Fertilization:** Fertilizer applications began April 12 and continued weekly until harvest. The fertilization regime of Carlson (1979) at a ratio of 125–60–159 ppm plus 5.5 ppm Fe was used throughout.

Table 1. Source of seed for 12 coniferous species

Scientific name	Common name	Source and location
Pinus sylvestris	Scots pine	Provincial Tree Nursery 0-67-48-N
Picea engelmannii	Engelmann spruce	Provincial Tree Nursery DG-60-13-6-74
Pinus banksiana	Jack pine	Provincial Tree Nursery DL-41-71
Abies balsamea	Balsam fir	Provincial Tree Nursery DS-80-25-4-79
Pseudotsuga menziesii var. *glauca*	Douglas-fir	Provincial Tree Nursery DC-61-154
Pinus contorta var. *latifolia*	Lodgepole pine	Provincial Tree Nursery DG-75-12-6-80
Picea glauca	White spruce	Provincial Tree Nursery DG-74-12-6-75
Picea mariana	Black spruce	Manitoba Seed lot #300, 1980
Pinus resinosa	Red pine	Manitoba Seed lot #286, 1980
Picea pungens	Colorado blue spruce	Oliver Tree Nursery 1979
Larix sibirica	Siberian larch	Oliver Tree Nursery Lot #1091, 1975
Pinus ponderosa	Ponderosa pine	Montana Near Colstrip

Table 2. Light quality and quantity of four treatments

	Light quality	Light quantity
Treatment 1	Fluorescent (40W)	18 hours
Treatment 2	Fluorescent (40W)	24 hours
Treatment 3	Sodium (400W)	18 hours
Treatment 4	Sodium (400W)	24 hours

Table 3. Light type, zeta ratio, and photosynthetic photon flux densities

Light type	Zeta ratio	PPFD (μmol m^{-2} s^{-1})
Fluorescent (6 × 40W)	5.213	67.88 (400–700 nm)
Sodium (1 × 400W)	2.155	167.90 (400–700 nm)
Natural daylight	1.119	69.06 (400–700 nm)

4. **Treatments:** The seedlings were randomly placed in one of four treatments as shown in Table 2.

5. **Harvesting:** Harvesting began November 10, 1983, except for Siberian larch, which was harvested September 6 due to excessive height growth that resulted in leaders being burnt by the lights. Each seedling was measured for three variables before being removed from the containers: height growth from the root collar to the terminal bud using a metre stick; root collar diameter using vernier calipers 2.5 cm up from the surface of the peat; and the number of branches on each seedling, including multiple leaders.

6. **Spectra:** Spectra of natural daylight and sodium and fluorescent lamps were taken using a Li-Cor Model LI/800 Spectroradiometer, equipped with microprocessor controller. Data output was recorded on a Beckman 10-inch strip chart recorder.

7. **Data analysis:** Data was analyzed using the SPSS package. ANOVA for two-way interactions was used to test for interactions between light quality and photoperiod. If interactions were not detected, a one-way ANOVA and Duncan's Multiple Range Test were used to show significant differences between means for each parameter within species.

RESULTS

Spectra

The spectral distribution of fluorescent lamps, high-pressure sodium lamps, and natural daylight are shown in Figures 1–3. Table 3 shows the zeta ratio and PAR from each light source. The zeta ratio is highest in fluorescent light and lowest in natural daylight. Although natural daylight was not used as a treatment, it did have opportunity to enter through the glass greenhouse. The spectra for the fluorescent lamps and sodium lamps were taken during the night to obtain the photosynthetic photon flux densities (PPFD) for the minimum light in each treatment.

Fluorescent lights (Fig. 2) have almost no emission in the far-red region and therefore set high R:FR ratios. High-pressure sodium light is emitted as a continuum throughout the visible spectrum with a significant far-red component. The blue content of the sodium lamp may be insufficient by itself for normal growth, but when augmented by natural daylight in glasshouses, growth is acceptably normal (Vince-Prue and Canham 1983).

It is generally considered that it is the spectral balance of the lamp rather than its overall light output that is likely to be important for morphogenetic effects (Vince-Prue and Canham 1983), and because of this, more emphasis will be placed on lamp type than on light intensity.

Colorado blue spruce

In Colorado blue spruce (Fig. 4), light quality accounts for most of the differences in growth (Table 4). Diameter growth almost doubles in the high-pressure sodium light, and height increases by approximately 30% more than under the fluorescent light (Table 5). Although light quality also affects the number of branches, the variation is so high that differences are not detectable using Duncan's Multiple Range Test. The root system of the trees grown under the sodium lamp are better developed and visually show a larger proportion of fine roots to suberized roots.

Lodgepole pine

Lodgepole pine (Fig. 5), like blue spruce, is significantly affected by light quality rather than photoperiod (Table 6). For all three parameters, height, diameter, and number of branches, light quality gives better growth (Table 7). Figure 5 shows that roots are also better developed in sodium light, but also noticeable is that in each light type, the 18-hour photoperiod produces a larger number of smaller roots than the 24-hour photoperiod.

Scots pine

Sodium lamps give significantly better height growth for Scots pine. Diameter growth is affected by both light quality and photoperiod (Tables 8 and 9). In fluorescent light, the 24-hour photoperiod gives greater diameter growth, whereas in sodium light the 18-hour photoperiod results in better growth. The root systems appear to be better developed in the 24-hour treatment for both lamp types (Fig. 6).

Ponderosa pine

Under high-pressure sodium lamps, ponderosa pine has better height growth, and diameter growth is doubled. Height growth is greater in the 18-hour photoperiod, but diameter growth is better in the 18-hour photoperiod for both light types. Significantly more branching was observed in the sodium light, although branching was minimal in all four treatments (Tables 10 and 11).

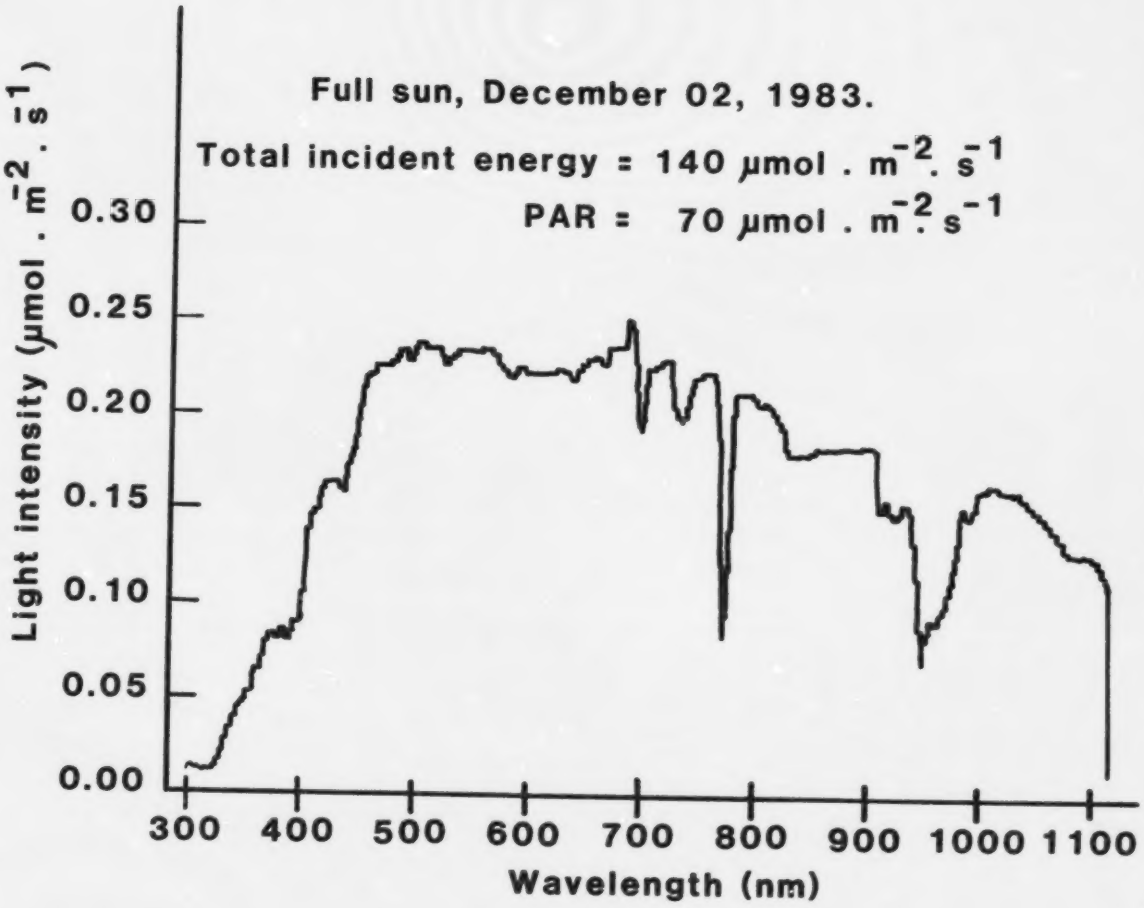

Figure 1. Spectral distribution of natural daylight.

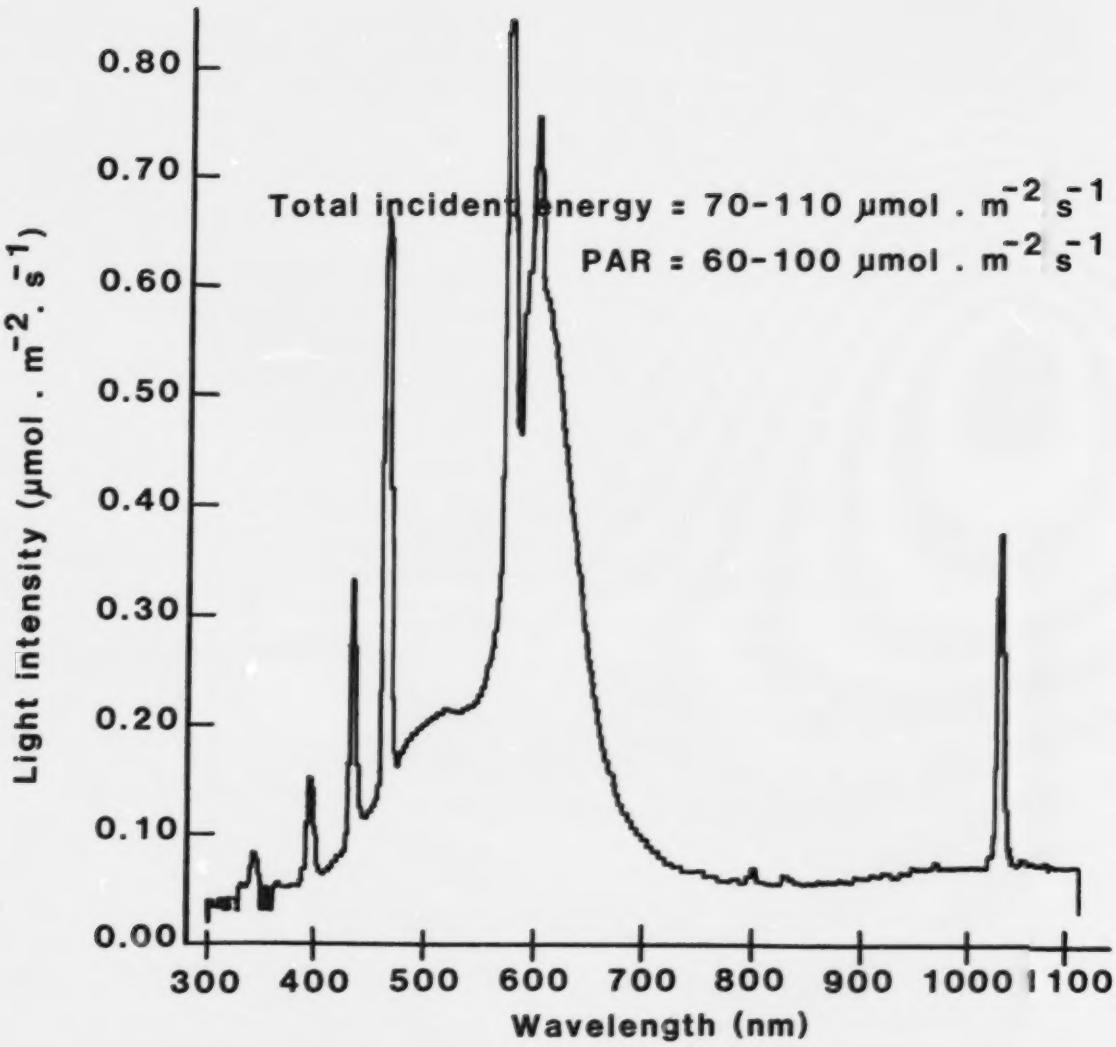

Figure 2. Spectral distribution of fluorescent light.

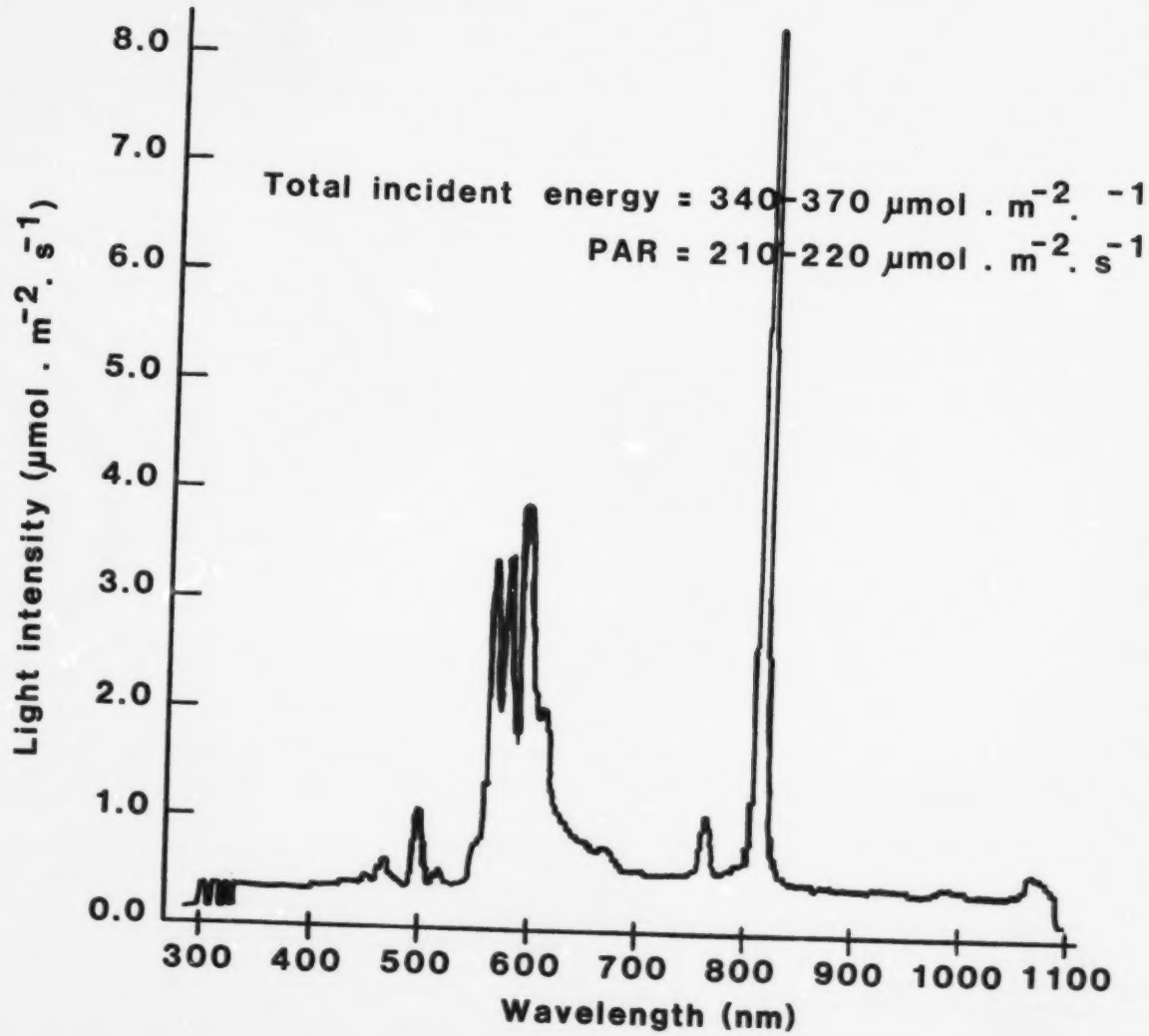

Figure 3. Spectral distribution of sodium light.

Figure 4. Colorado blue spruce seedlings at 36 weeks showing effects of four light treatments.

Table 4. Two-way analysis of variance of growth characteristics of Colorado blue spruce

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.728	0.005	0.801
Diameter	0.905	0.000	0.929
Branching	0.897	0.002	0.658

Table 5. Growth characteristics of Colorado blue spruce in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	33.111 ± 6.014[a]	33.522 ± 8.809[a]	43.378 ± 14.423[ab]	45.643 ± 11.273[b]
Diameter (cm)	0.431 ± 0.086[a]	0.443 ± 0.119[a]	0.749 ± 0.206[b]	0.750 ± 0.233[b]
Branches (no.)	22.889 ± 6.864[a]	25.000 ± 10.874[a]	37.333 ± 13.766[a]	36.000 ± 12.302[a]

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 5. Lodgepole pine seedlings at 36 weeks showing effects of four light treatments.

Table 6. Two-way analysis of variance of growth characteristics of lodgepole pine

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.513	0.000	0.432
Diameter	0.858	0.000	0.341
Branching	1.000	0.006	0.578

Table 7. Growth characteristics of lodgepole pine in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	17.148 ± 3.813^a	15.276 ± 4.247^a	19.609 ± 5.027^b	19.817 ± 4.867^b
Diameter (cm)	0.5299 ± 0.1216^a	0.4969 ± 0.1244^a	0.7228 ± 0.1559^b	0.6413 ± 0.1426^b
Branches (no.)	4.182 ± 1.896^a	4.366 ± 2.576^a	6.666 ± 3.940^b	6.405 ± 3.080^b

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Table 8. Two-way analysis of variance of growth characteristics of Scots pine

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.644	0.000	0.548
Diameter	0.008	0.000	0.553
Branching	0.060	0.000	0.830

Table 9. Growth characteristics of Scots pine in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	13.900 ± 3.279^{a}	15.689 ± 3.931^{a}	22.189 ± 6.388^{b}	21.956 ± 5.732^{b}
Diameter (cm)	0.3109 ± 0.0563^{a}	0.3889 ± 0.1043^{a}	0.5498 ± 0.1365^{c}	0.4798 ± 0.1069^{b}
Branches (no.)	1.111 ± 1.364^{a}	2.222 ± 1.642^{ab}	3.333 ± 1.732^{bc}	4.222 ± 1.394^{c}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 6. Scots pine seedlings at 36 weeks showing effects of four light treatments.

Table 10. Two-way analysis of variance of growth characteristics of ponderosa pine

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.177	0.000	0.357
Diameter	0.132	0.000	0.294
Branching	0.390	0.001	0.390

Table 11. Growth characteristics of ponderosa pine in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	9.744 ± 2.223^{a}	10.256 ± 1.461^{a}	14.767 ± 3.420^{b}	17.422 ± 5.345^{b}
Diameter (cm)	0.3311 ± 0.0808^{a}	0.3098 ± 0.0702^{a}	0.7462 ± 0.1328^{b}	0.6293 ± 0.2074^{b}
Branches (no.)	1.111 ± 1.054^{ab}	0.333 ± 0.707^{a}	2.444 ± 1.740^{b}	2.444 ± 1.560^{b}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Table 12. Two-way analysis of variance of growth characteristics of Siberian larch

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.825	0.099	0.088
Diameter	0.591	0.000	0.507
Branching	0.016	0.000	0.942

Table 13. Growth characteristics of Siberian larch in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	50.155 ± 9.613^{a}	55.366 ± 9.606^{ab}	61.888 ± 10.067^{b}	55.166 ± 11.295^{ab}
Diameter (cm)	0.5167 ± 0.0934^{a}	0.5521 ± 0.0718^{a}	0.7070 ± 0.0787^{b}	0.7032 ± 0.1031^{b}
Branches (no.)	2.000 ± 1.803^{a}	10.000 ± 7.124^{ab}	18.111 ± 11.677^{bc}	25.666 ± 12.052^{c}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Siberian larch

In Siberian larch, each of the three parameters reacts differently in the four treatments (Tables 12 and 13). Height growth is not significantly affected by photoperiod or light quality, although there are significant differences in the means using Duncan's Multiple Range Test. Diameter is significantly affected by light quality, with accelerated growth under the sodium lamps. The number of branches is significantly affected by both light quality and quantity although there is no interaction.

White spruce

Diameter growth of white spruce shows a two-way interaction with light quality and quantity (Table 14); in the lower intensity the longer photoperiod results in more growth, whereas under high intensity the shorter photoperiod gives better growth (Table 15). Both height and number of branches are affected by light quality, but due to the large variation within treatments there is a lot of overlap when Duncan's Range Test is used. Root growth shows more development in the sodium light, with the 18-hour photoperiod producing the largest number of fine roots (Fig. 7).

Douglas-fir

In Douglas-fir, all three parameters are significantly affected by light quality, but both height and diameter show interaction at the 5.6% level of significance (Tables 16 and 17). The 24-hour photoperiod in fluorescent light gives significantly better growth than the 18-hour, and sodium light is significantly better than fluorescent. Root development in Douglas-fir is more pronounced in the 18-hour sodium light than in the other three treatments (Fig. 8).

Balsam fir

Balsam fir shows two-way interactions with both light quality and quantity, for both height and diameter growth. Number of branches is not affected by any of the treatments (Table 18). Significant differences could not be found for any of the treatments. Root growth appears to be best developed in the 18-hour sodium light (Fig. 9).

Jack pine

Both height and diameter of jack pine are significantly affected by light quality, and number of branches depends on both light quantity and quality. Height is almost doubled under the sodium lamps compared to the fluorescent, and diameter shows a 33–50% increase. Although there is little significant difference between 18- and 24-hour sodium, the 24-hour sodium light gives a healthier root system (Tables 19 and 20, Fig. 10).

Engelmann spruce

The branching pattern in Engelmann spruce is significantly affected by both light quality and quantity, with more branches in the longer photoperiod under each light treatment (Tables 21 and 22). Diameter growth shows an interaction with lamp quality and photoperiod in the fluorescent light. Both height growth and root development appear to be better under sodium lamps (Fig. 11).

Black spruce

Both height and diameter in black spruce are affected by light quantity and quality (Table 23). For each lamp type, the longer photoperiod gave greater growth. Number of branches is significantly affected by light quantity rather than light quality (Table 24). Overall, the roots were poorly developed except in the 24-hour photoperiod (Fig. 12).

Red pine

For red pine, height growth is significantly affected by both light quantity and quality, diameter growth is affected by light quality, and number of branches is not affected by either (Tables 25 and 26). Using Duncan's Multiple Range Test, root, height, and diameter growth are significantly better in the sodium light (Fig. 13).

DISCUSSION

Species respond differently to R:FR, and in many cases these differences can be related to habitat (Morgan 1981). Generally shade-tolerant species are less responsive than shade-intolerant species, because FR has a greater effect on extension rate and petiole length for annual weeds or species from open habitats (Morgan and Smith 1979). The tolerance rating for species used in this experiment is listed in Table 27 (from Daniel et al. 1979).

Balsam fir is the only species used that is considered to be very shade-tolerant and shows two-way interactions for light quality and photoperiod. There are no detectable significant differences in height, diameter, or branching in any of the four treatments.

The tolerant species such as Engelmann, and black and white spruce exhibit more of a response to light

Table 14. Two-way analysis of variance of growth characteristics of white spruce

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.248	0.001	0.100
Diameter	0.648	0.000	0.015
Branching	0.070	0.000	0.381

Table 15. Growth characteristics of white spruce in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	25.722 ± 9.328^{a}	36.767 ± 16.751^{ab}	47.267 ± 10.470^{ab}	44.279 ± 6.128^{b}
Diameter (cm)	0.380 ± 0.088^{a}	0.486 ± 0.137^{a}	0.776 ± 0.076^{b}	0.691 ± 0.122^{b}
Branches (no.)	14.778 ± 12.814^{a}	25.778 ± 13.746^{ab}	34.222 ± 10.059^{abc}	38.000 ± 8.679^{bc}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 7. White spruce seedlings at 36 weeks showing effects of four light treatments.

Table 16. Two-way analysis of variance of growth characteristics of Douglas-fir

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.400	0.040	0.056
Diameter	0.781	0.002	0.056
Branching	0.160	0.007	0.443

Table 17. Growth characteristics of Douglas-fir in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	24.186 ± 8.502^{a}	38.025 ± 8.529^{ab}	39.563 ± 15.120^{b}	35.475 ± 4.305^{b}
Diameter (cm)	0.285 ± 0.285^{a}	0.400 ± 0.080^{b}	0.607 ± 0.135^{c}	0.563 ± 0.141^{c}
Branches (no.)	0.857 ± 1.069^{a}	11.250 ± 5.188^{b}	14.875 ± 14.817^{b}	19.750 ± 14.863^{b}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 8. Douglas-fir seedlings at 36 weeks showing effects of four light treatments.

Table 18. Two-way analysis of variance of growth characteristics of balsam fir

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.850	0.327	0.002
Diameter	0.929	0.193	0.003
Branching	0.382	0.098	0.164

Figure 9. Balsam fir seedlings at 36 weeks showing effects of four light treatments.

Table 19. Two-way analysis of variance of growth characteristics of jack pine

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.867	0.000	0.426
Diameter	0.377	0.000	0.792
Branching	0.000	0.000	0.304

Table 20. Growth characteristics of jack pine in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	11.578 ± 3.087^{a}	10.789 ± 2.163^{a}	17.856 ± 4.003^{b}	19.243 ± 4.603^{b}
Diameter (cm)	0.320 ± 0.110^{a}	0.404 ± 0.104^{a}	0.699 ± 0.093^{b}	0.740 ± 0.086^{b}
Branches (no.)	2.444 ± 1.104^{a}	4.778 ± 0.232^{a}	6.778 ± 0.972^{ab}	10.571 ± 1.988^{b}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 10. Jack pine seedlings at 36 weeks showing effects of four light treatments.

Table 21. Two-way analysis of variance of growth characteristics of Engelmann spruce

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.712	0.021	0.219
Diameter	0.287	0.000	0.034
Branching	0.003	0.000	0.329

Table 22. Growth characteristics of Engelmann spruce in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	19.544 ± 10.093^{a}	25.167 ± 12.544^{ab}	32.289 ± 11.316^{b}	29.244 ± 6.546^{ab}
Diameter (cm)	0.297 ± 0.077^{a}	0.411 ± 0.124^{b}	0.567 ± 0.114^{c}	0.528 ± 0.093^{c}
Branches (no.)	3.556 ± 3.941^{a}	12.778 ± 6.648^{b}	16.222 ± 9.066^{bc}	21.111 ± 5.465^{c}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 11. Engelmann spruce seedlings at 36 weeks showing effects of four light treatments.

Table 23. Two-way analysis of variance of growth characteristics of black spruce

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.004	0.013	0.785
Diameter	0.005	0.003	0.810
Branching	0.002	0.310	0.071

Table 24. Growth characteristics of black spruce in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	34.425 ± 7.978^{a}	50.267 ± 8.898^{b}	48.200 ± 21.387^{abc}	61.457 ± 10.200^{c}
Diameter (cm)	0.369 ± 0.097^{a}	0.616 ± 0.713^{b}	0.638 ± 0.328^{bc}	0.849 ± 0.194^{c}
Branches (no.)	29.625 ± 7.981^{a}	50.444 ± 12.630^{b}	41.250 ± 14.801^{b}	47.000 ± 7.348^{b}

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

Figure 12. Black spruce seedlings at 36 weeks showing effects of four light treatments.

Table 25. Two-way analysis of variance of growth characteristics of red pine

	Significance of F		
	Light quantity	Light quality	Two-way interaction
Height	0.017	0.000	0.822
Diameter	0.905	0.000	0.524
Branching	0.540	0.540	0.540

Table 26. Growth characteristics of red pine in four treatments

Parameter	Treatment[1]			
	1	2	3	4
Height (cm)	10.9444 ± 1.610^a	12.455 ± 1.229^a	15.911 ± 2.430^b	17.722 ± 2.384^b
Diameter (cm)	0.3622 ± 0.044^a	0.373 ± 0.030^a	0.623 ± 0.103^b	0.607 ± 0.045^b
Branches (no.)	1.556 ± 0.882^a	1.222 ± 0.667^a	1.222 ± 0.441^a	1.222 ± 1.093^a

[1] Within rows, means not followed by the same letter for each treatment parameter measured are significantly different ($P \leq 0.05$).

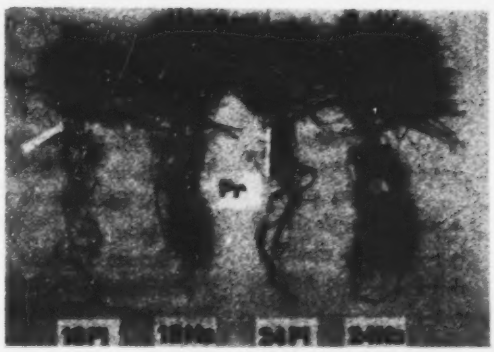

Figure 13. Red pine seedlings at 36 weeks showing effects of four light treatments.

Table 27. Tolerance ratings for 12 conifers

Species	Tolerance rating[1]
Colorado blue spruce	Intermediate
Lodgepole pine	Intolerant
Scots pine[2]	—
Ponderosa pine	Intolerant
Siberian larch[2]	—
White spruce	Tolerant
Douglas-fir	Intermediate
Balsam fir	Very tolerant
Jack pine	Very intolerant
Engelmann spruce	Tolerant
Black spruce	Tolerant
Red pine	Intolerant

[1] From: Daniel et al. 1979.
[2] Tolerance ratings not available for these species.

Table 28. Main effects on height growth of 12 conifers

Species	Light quantity	Light quality	Two-way interaction
Colorado blue spruce		+++[1]	
Lodgepole pine		+++	
Scots pine		+++	
Ponderosa pine		+++	
Siberian larch		++[2]	
White spruce		++	
Douglas-fir		+[3]	
Balsam fir			++
Jack pine		++	
Engelmann spruce		++	
Black spruce	++	+	
Red pine	+	++	

[1] +++ Significance of F between 0.00 and 0.005.
[2] ++ Significance of F between 0.006 and 0.01.
[3] + Significance of F between 0.01 and 0.05.

Table 29. Main effects on root collar diameter of 12 conifers

Species	Light quantity	Light quality	Two-way interaction
Colorado blue spruce		+++[1]	
Lodgepole pine		+++	
Scots pine	++[2]	+++	
Ponderosa pine		+++	
Siberian larch		+++	
White spruce		+++	+[3]
Douglas-fir		+++	
Balsam fir			+++
Jack pine		+++	
Engelmann spruce		+++	+
Black spruce	+++	+++	
Red pine		+++	

[1] +++ Significance of F between 0.00 and 0.005.
[2] ++ Significance of F between 0.006 and 0.01.
[3] + Significance of F between 0.01 and 0.05.

Table 30. Main effects on number of branches of 12 conifers

Species	Light quantity	Light quality	Two-way interaction
Colorado blue spruce		+++[1]	
Lodgepole pine		+++	
Scots pine		+++	
Ponderosa pine		+++	
Siberian larch	++[2]	++	
White spruce		+++	
Douglas-fir		+++	
Balsam fir			
Jack pine	++	++	
Engelmann spruce	++	++	
Black spruce	+++		
Red pine			

[1] +++ Significance of F between 0.00 and 0.005.
[2] ++ Significance of F between 0.006 and 0.01.

quality, but overall they exhibit less of a response than intolerant species, such as the pines. The species rated as having an intermediate tolerance (Colorado blue spruce and Douglas-fir) show varying responses. Red pine, which is rated as intolerant, also shows varying responses to the four treatments, thereby behaving as an intermediate-tolerance species.

Tables 28–30 show the main effects of light quality and photoperiod on height growth, root collar diameter, and number of branches for the 12 conifers.

Light quantity (photoperiod) has little effect on growth except for height and diameter growth of black spruce, height growth of red pine, and diameter growth of Scots pine. Photoperiod does increase the number of branches for 4 of the 12 species: Siberian larch, jack pine, Engelmann spruce, and black spruce. As this increase in number of branches occurs in both of the light types, the cause does not appear to be related to the R:FR ratio. Rather, the extended photoperiod may result in the production of excess photosynthates that may be channeled into lateral shoot development.

Smith (1982) found that light quality, especially R:FR, can modify branching and stem extension in herbaceous species, similar to what we see with the conifers. Our results indicate that both photoperiod and light quality were important in controlling the number of branches, while height and diameter growth were primarily controlled by light quality. The magnitude of the effect depends on the individual species considered.

In natural daylight, the R:FR remains relatively constant at 1.10 (Holmes and Smith 1977). The function of the phytochrome in the natural environment is to detect the R:FR of the incident spectrum and to perceive the spectral changes that occur in the far-red and subsequently control photomorphogenesis (Morgan 1981; Smith and Morgan 1983). In herbaceous plants, a linear relationship has been shown between phytochrome photoequilibrium and extension rate (Morgan and Smith 1978 as cited in Child et al. 1981). *Pinus radiata* also showed this similar relationship for seedlings (Morgan et al. 1983). Smith and Morgan (1983) have shown that decreasing R:FR ratios result in elongated growth of *Chenopodium album* seedlings.

The zeta ratios of the fluorescent and sodium lights in this experiment were 5.213 and 2.155, respectively. The seedlings under the sodium lamps with the lower zeta ratio exhibited better height growth (except black spruce), indicating that the R:FR did indeed exert a control over photomorphogenesis.

As the PPFD was not kept constant in this experiment, it is difficult to attribute the differences in growth solely to light quality. Although light quality is likely to be more important for morphogenetic effects (Vince-Prue and Canham 1983), the overall increase PAR in sodium light may increase photosynthetic rates, resulting in a faster rate of growth and a larger total accumulated growth.

Temperature regimes under the high-pressure sodium lamps were 3–4°C higher than under the fluorescent lamps. This increase in temperature, combined with the increase in light intensity, may make it more difficult to draw conclusions from this experimental data.

Looked at in another way, the benefits of increased light intensity and temperature with the sodium lights may promote the use of these lamps over the fluorescent lights, especially when these lights result in greater growth in a given amount of time.

Of the 12 conifers studied here, lamp type and photoperiod can be recommended for each species, with the understanding that light quality, temperature, and light intensity may be all or in part involved in increased growth (Table 31).

Table 31. Recommended lamp type and photoperiod for 12 conifers

Species	Lamp type	Photoperiod
Colorado blue spruce	Sodium	18 hour*
Lodgepole pine	Sodium	18 hour*
Scots pine	Sodium	18 hour*
Ponderosa pine	Sodium	18 hour*
Siberian larch	Sodium	18 hour*
White spruce	Sodium	18 hour*
Douglas-fir	Sodium	18 hour*
Balsam fir[1]	Fluorescent*	18 hour*
Jack pine	Sodium	18 hour*
Engelmann spruce	Sodium	18 hour*
Black spruce	Sodium*	24 hour*
Red pine	Sodium	18 hour*

* If no significant difference is detectable between the two photoperiods, then the shorter photoperiod is recommended due to the lesser energy requirement.

[1] No significant difference for any treatment.

CONCLUSION

The evidence presented here suggests that high-pressure sodium lamps promote faster growth of conifers in greenhouses compared to the commonly used fluorescent lamps. The increase in growth under the sodium lamps can be primarily attributed to light quality, although light intensity and temperature cannot be excluded from playing a role. Photoperiod exerts its greatest effect by causing an increase in the number of branches in long exposure, and has little effect on height and diameter growth in the species studied.

The observed differences between the sodium and fluorescent lamps are generally accepted to be due to the R:FR, which is perceived by phytochrome and subsequently controls photomorphogenesis.

Although high-pressure sodium lamps have a higher initial cost, replacement is less often required, and added benefits through increased light intensity and possibly temperature can be achieved. If sodium lights are to be used in growth chambers, supplementation with blue light may be necessary.

Sodium lamps produce healthy, vigorous-looking conifers with better developed root systems that may aid in establishment when planted outdoors. Outplanting and monitoring of growth would help to determine the extent to which this promotive effect can be used. The advanced root development under sodium lights suggests that establishment and resumption of growth following outplanting would be quicker with seedlings grown under these lights.

REFERENCES

Carlson, L.W. 1983. Guidelines for rearing containerized conifer seedlings in the prairie provinces. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-214E.

Child, R.; Morgan, D.C.; Smith, H. 1981. Morphogenesis in simulated shade light quality. Pages 409–422 *in* H. Smith, ed. Plants and the daylight spectrum. Academic Press, New York, N.Y.

Daniel, T.W.; Helms, J.A.; Baker, F.S. 1979. Principles of silviculture. 2nd ed. McGraw-Hill Book Co, New York, N.Y.

Holmes, M.G.; Smith, H. 1977. The function of phytochrome in the natural environment II. The influence of vegetation canopies on the spectral energy distribution of natural daylight. Photochem. Photobiol. Rev. 25:539-545.

Morgan, D.C. 1981. Shadelight quality effects on plant growth. Pages 205–222 *in* H. Smith, ed. Plants and the daylight spectrum. Academic Press, New York, N.Y.

Morgan, D.C.; Smith, H. 1976. Linear relationship between phytochrome photoequilibrium and growth in plants under simulated natural radiation. Nature (Lond.) 262:210–211.

Morgan, D.C.; Rook, D.A.; Warrington, I.J.; Turnbull, H.L. 1983. Growth and development of *Pinus radiata* D. Don: the effect of light quality. Plant, Cell and Environment 6:691–701.

Smith, H. 1982. Light quality, photoperception, and plant strategy. Annu. Rev. Plant Physiol. 33:481–513.

Smith, H. Morgan, D.C. 1983. The function of phytochrome in nature. Encyclopedia of Plant Physiology. New Series Volume 16B:491–517.

Vince-Prue, D.; Canham, A.E. 1983. Horticultural significance of photomorphogenesis. Encyclopedia of Plant Physiology. New Series Volume 16B:518–544.

Wheeler, N. 1979. Effect of continuous photoperiod on growth and development of lodgepole pine seedlings and grafts. Can. J. For. Res. 9:276–283.

FIELD SHELTERBELT INVESTIGATIONS—INDIAN HEAD

John Kort
PFRA Tree Nursery
Indian Head, Saskatchewan

The PFRA Tree Nursery began producing trees in 1902 as a source of fuel wood and shelter for prairie settlers. Droughts in the 1930s accompanied by high winds caused severe soil drifting and motivated tree plantings for field shelterbelts as a soil erosion control measure (Pelton 1976). Since then, the planting of field shelterbelts to prevent soil erosion has been a continuous activity on the prairies.

The present level of activity by PFRA, Agriculture Canada research stations, and universities located near areas of soil erosion indicates the concern with which authorities view the problem of soil erosion. It is very difficult to quantify the soil losses due to wind erosion or the efficiency of field shelterbelts in controlling erosion. There is a general consensus among farmers owning mature field shelterbelts that the belts are effective in preventing erosion (Durand 1978; Sutton 1983) and that they are generally worthwhile (Sutton 1983). Field shelterbelts should be used to complement other effective conservation practices, such as minimum tillage and reduced use of summer fallow, instead of as a substitute for them, since, at best, they only stop a portion of the erosion (Hagen 1976).

Planting field shelterbelts as a soil conservation measure has several advantages; it is a long-term solution to a long-term problem and is therefore effective regardless of changes in land ownership, land management, or cropping practices.

Even though farmers are interested in controlling soil erosion, short-term concerns may be the main factors in the decision to plant or not to plant. A number of incidental benefits and problems are associated with field shelterbelts and must be considered, as they will affect this decision.

Incidental benefits of field shelterbelts have been observed:

1. Snow that becomes trapped by the shelterbelt increases the moisture content in nearby soil. Resultant yield increases have been found in the adjacent crop for a distance of 1–10 H from the shelterbelt, where H is the shelterbelt height (Pelton 1976; Peterson 1971; Read 1964).

2. Shelterbelts reduce direct, wind-related damage to the leeward crop, including blowing out of seed or seedlings, soil particle damage to tender crops, lodging of crops, and wind-blowing of swaths of some crops, such as rapeseed and flaxseed (Sutton 1983).

3. Shelterbelts improve habitat for bees (e.g., leaf-cutter bees for an adjacent field of alfalfa).

4. Effects on wind speed have been reported to be cumulative (Hagen 1976). Although quantitative studies have not been done on cumulative effects on soil and snow retention, the nursery recommends multiple plantings of shelterbelts.

Incidental problems related to field shelterbelts have been observed:

1. Reduction in crop growth is often seen adjacent to the shelterbelt. This reduction appears to vary with tree height (Frank et al. 1976), species, and the adjacent crop (Umland 1979).

2. Excessive entrapment of snow due to very dense shelterbelts can delay spring working of the soil next to the belt and may contribute to leaching of nutrients (Samson 1979).

3. Land requirements by multi-row shelterbelts or by species of trees that spread excessively reduce the attractiveness of planting such belts. (Samson 1979).

4. Mature, nonhardy, or diseased trees may lose branches, which fall into the field or die entirely. In such cases, maintenance of the shelterbelt is required and, eventually, entire shelterbelts will have to be renovated due to their age (Suedkamp 1979).

Studies have been initiated on the nature of competition by shelterbelts with adjacent crops, and on various aspects of field shelterbelts to optimize benefits and minimize problems. Studies can be grouped into three categories:

A. **Promotion** (This assumes that field shelterbelts have their place on the Canadian prairie, an assumption that has been held since the 1930s).

- targeting areas where wind erosion is a major problem
- analysis of costs vs. benefits of a properly located, designed, and maintained field shelterbelt
- study of yield effects of shelterbelts
- quantification of soil erosion and its costs

B. Design

- evaluation of species and spacing
- designing to allow for later shelterbelt maintenance and renewal

C. Management

- studies on thinning, trimming, and pruning (effects and techniques)
- root-pruning to reduce competition (effects on trees and adjacent crops)
- techniques of shelterbelt renovation

CONCLUSION

Studies on the benefits, problems, and management techniques related to field shelterbelts need to be carried out. As noted by Read (1964): "Windbreaks should ordinarily be planted with one primary purpose in mind ... The primary purpose ... should have exclusive priority in deciding as to species, arrangement, and spacing that will influence windbreak structure." On the Canadian prairies, the planting of field shelterbelts is a soil conservation measure and should be evaluated as such.

REFERENCES

Durand, R. 1978. An evaluation of the efficacy of tree shelterbelts in the prairie provinces. Lakehead University, Thunder Bay, Ontario. Undergraduate thesis.

Frank, A.B.; Harris, D.G.; Willis, W.O. 1976. Influence of windbreaks on crop performance and snow management in North Dakota. Pages 41–48 *in* R.W. Tinus, ed. Shelterbelts on the Great Plains. Great Plains Agric. Counc. Publ. No. 78. Denver, Colorado.

Hagen, L.J. 1976. Windbreak design for optimum wind erosion control. Pages 31–36 *in* R.W. Tinus, ed. Shelterbelts on the Great Plains. Great Plains Agric. Counc. Publ. No. 78. Denver, Colorado.

Pelton, W.L. 1976. Windbreak studies on the Canadian prairie. Pages 64–68 *in* R.W. Tinus, ed. Shelterbelts on the Great Plains. Great Plains Agric. Counc. Publ. No. 78. Denver, Colorado.

Peterson, L.O.T. 1971. Some effects of shelterbelts. PFRA Tree Nursery, Indian Head, Saskatchewan.

Read, R.A. 1964. Tree windbreaks for the central great plains. U.S. Dep. Agric., Agric. Handb. No. 250. Washington, D.C.

Samson, L.J. 1979. Thinning—to achieve desired density in field shelterbelts. Pages 91–94 *in* Windbreak management. Great Plains Agric. Counc. Publ. No. 92. Norfolk, Nebraska.

Suedkamp, J.F. 1979. Long-range windbreak management schemes. Pages 5–10 *in* Windbreak management. Great Plains Agric. Counc. Publ. No. 92. Norfolk, Nebraska.

Sutton, V. 1983. An evaluation of landowners' attitudes toward field shelterbelts in agro-Manitoba: A case study in the Lyleton area. University of Manitoba, Winnipeg, Manitoba.

Umland, E.R. 1979. Root-pruning as a management technique. Pages 107–112 *in* Windbreak management. Great Plains Agric. Counc. Publ. No. 92. Norfolk, Nebraska.

FORMATION OF THE TREE NURSERY WEED CONTROL COMMITTEE

L.K. Alspach
Tree Nursery
Indian Head, Saskatchewan

A nursery herbicide workshop was held at the PFRA Tree Nursery in Indian Head, Saskatchewan on July 17 and 18, 1984. It was sponsored by the nursery, with 29 participants in attendance. Participants included nurserymen and research workers from across Canada and the northern Great Plains of the United States.

Two guest speakers were invited: Dr. David South, of Auburn University, Auburn, Alabama and Dr. Larry Abrahamson, of the State University of New York, Syracuse, New York. Dr. South delivered a presentation on the organization of a forest nursery herbicide cooperative, as well as a summary of the results achieved by the Auburn University Cooperative. Dr. Abrahamson gave an address on a similar topic for a different geographical area; he spoke on forest nursery cooperatives in the northern United States and gave highlights of research results.

Other topics covered on the first day of the workshop included: herbicides registered for use in tree nurseries and those with potential for registration; a review of the procedure for minor use registration; and an explanation of the function of the Expert Committee on Weeds. Also presented were various research reports on herbicide trials in tree nurseries. The first day ended with a tour of the tree nursery's herbicide plots.

On the second day of the workshop, the nurserymen provided a report on herbicide use and weed control practices and problems at their nurseries. Discussion at the end of the second day resulted in a decision to form two ongoing organizations: a Tree Nursery Weed Control Committee and a Herbicide Committee of Northern Plains Tree Nurseries.

A small organizing committee was formed to coordinate the Tree Nursery Weed Control Committee. Members of this organizing committee include: Ron Hallett, Canadian Forestry Service (CFS), Fredericton, New Brunswick; Eileen Harvey, CFS, Edmonton, Alberta; John Maxwell, British Columbia Forestry Service, Surrey, British Columbia; Charles Waywell, Ontario Ministry of Natural Resources, Guelph, Ontario; and Bruce Neill, Canada Department of Agriculture, Indian Head, Saskatchewan.

Objectives of this committee are as follows: to conduct a survey of all tree nurseries in Canada to obtain detailed information about their current weed control programs and to obtain any weed control data that would be suitable for submission to the Expert Committee on Weeds; to set priorities on the choice of herbicides and species for submission for minor use registration; to prepare a release about the workshop and the creation and objectives of the newly formed committee; to contact CFS headquarters in Ottawa, regional nursery specialists and associations of tree nurserymen, regional directors of CFS labs, and the appropriate summarizers of the Expert Committee on Weeds; and to establish a standard testing and reporting procedure for herbicide testing in Canadian tree nurseries.

The second group or committee, the Herbicide Committee of Northern Plains Tree Nurseries, will consist of nurserymen of a common geographical area who produce similar tree nursery crops. They will meet every 2 years to exchange information, discuss current herbicide practices, weed control problems, and any ongoing or planned herbicide research. The tentative location for the 1986 meeting of this committee is Lincoln-Oakes Nursery in Bismarck, North Dakota.

Copies of the proceedings of the Nursery Herbicide Workshop will be available in late 1984 from:

Dr. Bruce Neill
PFRA Tree Nursery
Indian Head, Saskatchewan
Canada
S0G 2K0

ACKNOWLEDGMENTS

Thanks and appreciation go to the speakers, especially R.F. Huber, our guest speaker from British Columbia, who took the time to prepare and present their papers. The tours of Spencer-Lemaire Industries and Beaver Plastics Limited and the accompanying refreshments are gratefully acknowledged. The help of Wendy Mills and Frank Dendwick in collecting money, giving out name tags, and organizing refreshments is also appreciated.

BUSINESS MEETING

The 1985 Prairie Federal-Provincial Meeting will be held at Prince Albert, Saskatchewan at approximately the same time next year.

It was decided to expand attendance and invite nurserymen from Dryden and Thunder Bay Nurseries in Ontario, and from Red Rock Nursery, Prince George, British Columbia. An increased effort will be made next year to attract industry and private growers in Alberta, Saskatchewan, and Manitoba.

ATTENDEES AT THE PRAIRIE FEDERAL-PROVINCIAL NURSERYMEN'S MEETING

Lyle K. Alspach
Tree Nursery Division
PFRA
Indian Head, Saskatchewan
S0G 2K0

Jim Atkinson
Pineland Provincial Forest Nursery
Box 45
Hadashville, Manitoba
R0E 0X0

Peter N. Au
Pine Ridge Forest Nursery
Alberta Forest Service
Department of Energy and Natural Resources
Box 750
Smoky Lake, Alberta
T0A 3C0

Joe Chernysh
Forestry Division
Saskatchewan Department of Parks and Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

John Cruickshank
Tree Nursery Division
PFRA
Indian Head, Saskatchewan
S0G 2K0

Dale Currey
Blue Ridge Lumber Ltd.
Box 1079
Whitecourt, Alberta
T0E 2L0

Ian J. Dymock
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Ivor K. Edwards
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Rodger Hamilton
Pine Ridge Forest Nursery
Alberta Forest Service
Department of Energy and Natural Resources
Box 750
Smoky Lake, Alberta
T0A 3C0

Eileen M. Harvey
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Ralph F. Huber
British Columbia Ministry of Forests
1450 Government Street
Victoria, British Columbia
V8W 3E7

Barry Hutchison
Box 1257
Whitecourt, Alberta
T0E 2L0

Jim M. Kinghorn
Beaver Plastics Ltd.
12806 - 63 Street
Edmonton, Alberta
T5A 0W2

John Kort
Tree Nursery Division
PFRA
Indian Head, Saskatchewan
S0G 2K0

Larry Lafleur
Pine Ridge Forest Nursery
Alberta Forest Service
Department of Energy and Natural Resources
Box 750
Smoky Lake, Alberta
T0A 3C0

Continued on next page.

John McCutcheon
Forestry Division
Saskatchewan Department of Parks and
Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Frank W. McKinney
Clearwater Provincial Forest Nursery
Department of Natural Resources
Box 2550
The Pas, Manitoba
R9A 1M4

John Murray
Joffre Greenhouses
R.R. #2
Lacombe, Alberta
T0C 1S0

Al Nanka
Canadian Forestry Service
104 - 180 Main Street
Winnipeg, Manitoba
R3C 1A6

Bruce Neill
Tree Nursery Division
PFRA
Indian Head, Saskatchewan
S0G 2K0

Larry Rempel
Forestry Division
Saskatchewan Department of Parks and
Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

John Thompson
Forestry Division
Saskatchewan Department of Parks and
Renewable Resources
P.O. Box 3003
Prince Albert, Saskatchewan
S6V 6G1

Joe Van Dyk
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Kathy Yakamachuck
Pine Ridge Forest Nursery
Alberta Forest Service
Department of Energy and Natural
Resources
Box 750
Smoky Lake, Alberta
T0A 3C0

Harry Zalasky
Northern Forest Research Centre
5320 - 122 Street
Edmonton, Alberta
T6H 3S5